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Context-Sensitive Solution: concept, demand, and potential of the method for modernizing transportation planning

The Context Sensitive Solution, a terminology created in the early 2000s in the USA and still pending translation to Portuguese, configures a methodology to support promoting participation and inclusion of different actors in the transport planning processes. The approach is an alternative to the complex demand for contemporary transport planning. It has shown promising results in studies of urban roads for communities, mainly because it aims to serve users through compatibility with the surroundings, community, and environment. Although Context Sensitive Solution originated in the early 2000s and with proven maturity in projects involving interventions on highways and major avenues in a peri-urban environment in large North American cities, its dissemination has not yet reached the peak of its potential and demand. The growing complexity of the transport and territorial planning policies makes it imperative to study solutions compatible with demand that address the problem in a comprehensive, transparent and participatory manner. As a management tool, the Context Sensitive Solution considers the values of stakeholders and the local community, in contrast to conventional practices of planning transport works that directly intervene in the urban space in which traditionally there is a lack of approaches that integrate local interests and values. In Brazil, the urban landscape's enormous dynamics and the city's structure's functional characteristics justify the academy's inclination to understand and adapt the Context Sensitive Solution to the local characteristics and desires. Notwithstanding the already established negative aspects such as the loss of connectivity, disruption in the local microeconomy, and encouraging a drop in security that impact the quality of life for the population bordering highways and significant avenues, there are also severe changes in the landscape, the natural flow of drainage, habitat segregation, noise, light and particulate matter pollution, as well as fauna mortality. Given this scenario, our manuscript introduces the concept of the Context Sensitive Solution and discusses its current demand and potential for use in planning and managing space nearby proposed or constructed critical linear infrastructure projects with the potential to interfere with the landscape and functions of urban locations. Furthermore, an in-depth literature review focused on the theme made it possible to know and measure the state of the art of the technique and identify the gains proposed by the method, for which situations there is a collaborative and holistic approach to the problem, and the Solution stands out.

Keywords: Context Sensitive Solution; Transportation planning; Multicriteria analysis; Participatory model.

Context Sensitive Solution: conceito, demanda e potencial do método para modernização do planejamento de transporte

O Context Sensitive Solution, termo cunhado há nos Estados Unidos quase duas décadas e ainda sem tradução para o português, configura uma metodologia de suporte ao planejamento de transporte para promover participação e inclusão de diferentes atores. Sua aplicação como alternativa à complexa demanda do planejamento de transportes contemporâneo tem demonstrado resultados promissores em estudos de vias urbanas para comunidades, sobretudo por almejar atender aos usuários por meio de uma compatibilidade com o entorno, comunidade e meio ambiente. Embora criado ainda no início dos anos 2000 e com comprovada maturidade em projetos de intervenções de rodovias e grandes avenidas em ambiente periurbano em grandes cidades norte-americanas, sua disseminação ainda não atingiu o alcance a altura de seu potencial e de sua demanda. A crescente complexidade das políticas envolvidas no planejamento de transporte e no planejamento territorial torna imperativo o estudo de soluções compatíveis à demanda e que abordem o problema de forma ampla, transparente e participativa. Como instrumento de gestão, o Context Sensitive Solution considera valores dos stakeholders e da comunidade local, em contraponto às práticas convencionais de planejamento de obras de transportes que interveem diretamente no espaço urbano em que tradicionalmente ocorre a ausência de abordagens que integrem os interesses e valores locais. No Brasil, a grande dinâmica da paisagem urbana e das características funcionais da estrutura da cidade justificam que a academia se incline para compreender e adaptar o Context Sensitive Solution às características e anseios locais. Não obstante aos já consagrados aspectos negativos como a perda de conectividade, ruptura na microeconomia local e estímulo a queda na segurança que impactam a qualidade de vida da população lindeira às rodovias e grandes avenidas, destacam-se também severas alterações na paisagem e no fluxo natural de drenagem, segregação de habitats, poluição sonora, luminosa e por partículas em suspensão, além da mortalidade de fauna. Neste sentido, o presente manuscrito apresenta ao leitor o conceito do Context Sensitive Solution, e discute sua real demanda e seu potencial de uso para planejamento e gestão do espaço em áreas adjacentes a grandes obras de infraestruturas lineares com potencial de interferência na paisagem e nas funções urbanas locais. Uma profunda revisão acerca do tema permitiu conhecer e mensurar o estado da arte da técnica, bem como identificar os ganhos propostos pelo método, para o qual se destacam as situações em que há uma abordagem colaborativa e holística do problema e da solução.

Palavras-chave: Context Sensitive Solution; Planejamento de transportes; Análise multicritério; Modelo participativo.

Topic: **Planejamento Urbano**

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INTRODUCTION

The environmental review and public participation processes mandated by the National Environmental Policy Act (NEPA), followed by 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act – A Legacy for Users (SAFETEA-LU) have become overly time-consuming and costly in transportation planning. More than ever, the implementation of an innovative method for transportation planning was needed by transportation and land-use authorities. This pressing issue busted landscape architectures, geographers, and the engineering team to propose the Context-Sensitive Solution (CSS).

The CSS was established in 2003 by the U.S. Department of Transportation (AASHTO - The American Association of State Highway and Transportation Officials and FHWA - Federal Highway Administration) in response to the practical need for efforts that proactively integrate the participation of public managers and community members (LIMA et al., 2017). The CSS consists of a methodological-comprehensive-inclusive approach to support the development of transport projects, considering and balancing inputs from different perspectives (economic, technical, environmental, social, cultural, historical, and aesthetic) while preserving or improving safety and mobility (KUMAR et al., 2020).

> CSS is the result of developing transportation projects that serve all users and are compatible with the surroundings through which they pass—the community and environment—successful CSS results from a collaborative, multidisciplinary, holistic approach to transportation planning and project development. CSS in the transportation planning or project development process identifies es objectives, issues, and concerns based on stakeholder and community input at each level of planning and design, for example, network, corridor, and project. (ITE, 2006)

The main characteristic of this approach is the harmony and integration between all factors, where the elements are not examined separately but in different contexts that interact and need to be evaluated and matched in the best possible way (LIMA et al., 2016). The characteristics and particularities of each neighborhood, including social contexts such as cultural aspects and factors that may promote or inhibit local economic sustainability (LAALY et al., 2017).

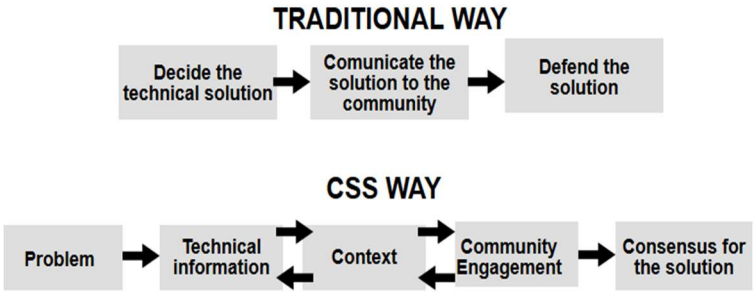

Figure 1: Contextualization of the Context-Sensitive Solution. **Source**: Souza et al. (2016).

CSS principles applied to the planning and design of a transportation project can make the difference between a successful project valued by the community or an embattled project taking years or even decades to complete, if ever. Unfortunately, numerous examples of transportation projects have halted or been held up in the courts long before the final design is reached (ITE, 2006). According to Stich et al. (2011), the CSS implementation depends on the organization, treatment, and data analysis, as well as a mechanism that promotes the decision-making process in a participatory way. The innovative aspect of CSS is marked by the

synergy of actions and actors from different perspectives to understand the problem and anticipate a mutual solution before the engineering construction phase. Figure 1 compares the traditional method of solution proposition and CSS.

An approach that considers CSS in planning does not mean solving all problems but tends to reasonably minimize delays and setbacks, as it involves community interests and values, as well as working solutions that reconcile the purpose of the project and the context in which they are inserted. For example, the New York State Department of Transportation states:

> Context Sensitive Solutions is a philosophy wherein safe transportation solutions are designed harmoniously with the community. CSS strives to balance environmental, scenic, aesthetic, cultural, and natural resources and community and transportation service needs. Context-sensitive projects recognize community goals and are designed, built, and maintained to be sustainable while minimizing disruption to the community and environment. (ITE, 2006)

Even considering that most of the CSS projects concern urban or peri-urban case studies such as local Transit-Oriented Development (TOD) and Traffic Calming approaches, the robustness of CSS also enables us to consider its application to extensive areas. For example, figure 2 shows the linear green corridor integrated into downtown Boston revamped historical port area after building the 2-kilometer-long underneath segment of Interstate 95.

Figure 2: Replacement of the aerial and superficial i-95 by underneath construction across the historical port district of Boston. Comparative scenarios of the area before and after the severe context-sensitive Solution[1].

Given the above introduction, this work aims to clarify and disseminate the CSS so that it can be incorporated into urban and transport planning as an inclusive model, adding greater assertiveness and acceptance to projects. Specifically, the CSS decision-making process, which involves different preferences from different audiences, has many synergies with environmental systems modeling and geoprocessing tools. Hence, this paper aims to clarify the CSS approach to land-use managers, transportation practitioners, and decision-makers for greater effectiveness and efficient urban and transport planning.

[1] Adapted from http://www.bostonroads.com/

THEORETICAL DISCUSSION

The intricate synergies between geographic context and transportation

The strong correlation between economic development and transport infrastructure has been the starting point of many academic investigations. However, transport planning, which is intrinsically related to land use and occupation and territorial planning, currently feels the effects of the obsolescence of methodologies incompatible with the current state of the art (NOBREGA, 2007). Therefore, the literature emphasizes the importance of integrating environmental, economic, social, political-administrative, and legal components in transportation planning (SOUZA et al., 2020). Furthermore, such components are responsible for compiling scenarios, typically competing with each other, which are generally confronted and combined to find a balance between benefit and cost for project implementation (STICH et al., 2011).

Territorial and transport planning are essential for establishing connections within communities and urban centers (KOHLSDORF, 1985). As mentioned earlier, some problems are common to the two sectors concerning transport projects, such as incompatibility with the surroundings, impacts on communities, focus on mobility without addressing other community values, imbalance in environmental impacts, and lack of stakeholder participation during planning (Stamtiadis, 2011). Figure 3 shows a case study for qualifying and quantifying significant changes within a 400-meter buffer surrounding a metro station.

Class	2002		2011		2021		2002-2011 Inter class Difference	2011-2021 Inter class Difference
	Area (m²)	%	Area (m²)	%	Area (m²)	%		
Equipment	152979.54	30.44	123471.25	24.57	168269.46	33.49	-19.29%	36.28%
MultUse	0.00	0.00	33364.80	6.64	37347.83	7.43	33364.80%	11.94%
SingleUse	113898.53	22.67	110739.54	22.04	106982.24	21.29	-2.77%	-3.39%
Open	187111.54	37.24	159338.11	31.71	92432.55	18.39	-14.84%	-41.99%
Streets	48498.39	9.65	75574.30	15.04	97455.92	19.39	55.83%	28.95%
Total	502488.00	100	502488.00	100	502488.00	100		

Figure 3: Time elapsed analysis of the significant changes within a 400-meter buffer surrounding a metro station in Belo Horizonte, Brazil. The investigation synthesized five main classes of urban land use and quantified metrics towards a context-sensitive solution to help decision-makers assess the infrastructure's impact on the local community.

Notwithstanding, land use is a standard criterion for characterizing urban development and estimating vehicle trip generation. Therefore, land use is an essential contributor to context and a significant factor in the selection of design criteria, assembly of the cross-section components, and allocation of the geometric highway design and local-regional logistic parameters. In addition to having a fundamental impact on travel demand, variations in adjacent land use affect the width and design of the roadside, the part of the thoroughfare between the curb and edge of the right-of-way, including the sidewalks (ITE, 2006).

According to Stich et al. (2011), for planning to be successful, building consensus on the best possible Solution is essential so that the community takes ownership of the results. The streets are spaces that predominate in public areas, impacting urban forms and comfort levels (KOHLSDORF, 1985). As they are shared public equipment, their functionality should meet, in a maximized way, the different types of use (KARNDACHARUK et al., 2014). Thus, it is possible to create environments more conducive to pedestrians so that they can transit in a way that is compatible with vehicles. Historically, urban streets designed to serve multiple functions, in addition to just transporting people and goods, have gained prominence and attention. The crucial functions outside mobility are vast: economic, social, and environmental (DOVER et al., 2013).

A simple definition of urban and regional planning deals with ordering cities and solving their problems through creating and developing programs that can improve or revitalize certain aspects, providing the inhabitants with a better quality of life (KOHLSDORF, 1985). Urban planning emerged as a response to the problems faced by cities, both those that were not solved by modern urbanism and those that were caused by it.

However, urban space is subject to high levels of complexity, whether in a territorial organization (BOEING, 2018; CLIFTON et al., 2008) and its legislation or the population's behavior and interrelationship (BATTY, 2003). Therefore, it is essential to understand that the urban phenomenon is dynamic, the result of activities and the history of each place, and, therefore, evolves. Furthermore, the speed of urban transformations contrasts with the slowness of public management in providing the necessary changes for society. Therefore, the city starts to be seen as the product of particular historical contexts and no longer as an ideal model to be conceived by urban planners (KOHLSDORF, 1985).

Urban planning needs a multidisciplinary approach, no longer an activity restricted to the architect's role, starting to bring together professionals from different areas of knowledge to provide a more holistic view of the city's problems (CLIFTON et al., 2008; SHAO et al., 2011). Furthermore, it is necessary to foresee future scenarios, with possible impacts, whether positive or negative, in order to assess the interests of different social groups. In this sense, geoprocessing and modeling environmental systems can support predicting and simulating future scenarios, referencing the landscape's dynamics (SAMPAIO, 2014).

Road and transport planning is part of the urban context, enabling the flow of vehicles and population at various scales (CLIFTON et al., 2008; DAVIS et al., 2009). Therefore, it has a fundamental role in urban mobility (JIANG, 2016). In addition, it also reflects on how the spaces will be appropriated and used by the community. According to Cervero (2015), the environmental impacts and greenhouse gas emissions are directly linked to "sustainable mobility" and "sustainable urbanism," issues which discussion became common in nations with advanced economies by understanding that sustainable transportation is a critical component of sustainable development. Cervero (2015) also states that coordination and transparency of data, values and methods and common interest of the actors are key to developing and implementing good projects. The most livable cities worldwide have intermodal systems that balance highway and public transit modes by providing for pedestrians, bicyclists, and paratransit (DITTMAR et al., 2004; VUCHIC, 1999).

Improving methods for supporting decisions in complex geographic environments

Practicing poor transportation planning brings several lessons learned related to current problems such as environmental impacts, disorderly and unplanned occupation of land use, logistical deficiency, traffic, pollution, and road safety, which currently underpin public and environmental policies in transport (TISLER et al., 2022; LEON et al., 2020). According to Souza et al. (2020), decisions in critical infrastructure projects are generally complex and cannot be treated as independent disciplines, whether for logistical studies of origin and destination, accessibility, or environmental issues.

The physical interventions resulting from a road project generate reflexes in the geographical context. Likewise, interventions in the physical space, or simply in the legislation or policy governing the territory, impact the transport system (NOBREGA et al., 2012). From an environmental point of view, the densification of land transport networks can trigger negative consequences such as the fragmentation of natural habitats (TISLER et al., 2022; SINGLETON et al., 1999; CLEVENGER et al., 2002; FURNEY et al., 2008), as well as problems with intra-urban accessibility. In transport environmental impact studies, for example, factors that can positively and negatively influence the geographic context of the area impacted by a road project are considered (NOBREGA et al., 2016). Figure 4 synthetizes a geographic-oriented model for early assessment of socio-environmetnal impacts in sensitive rural areas.

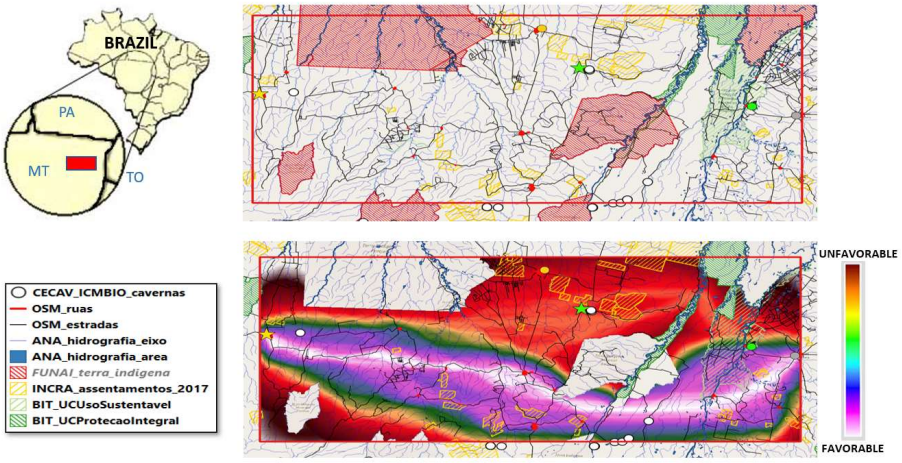

Figure 4: Comprehensive contextual analysis for antecipating environmental impacts and impacts on traditional comunities of Xingu National Park due to a new-proposed road. **Source**: Nobrega (2020).

The complexity of variables in the transport and land use planning process requires computer models to support decision-making. As a result, there is a growing demand for geoprocessing techniques as a key to spatial decision support systems (SAATI, 2000). The demand for structured spatial information to support transport management and planning was one of the main factors responsible for the advances made by GIS (SADASIVUNI et al., 2009). Still, in the 1980s, according to Stich et al. (2011), the United States Census Bureau developed the TIGER (Topologically Integrated Geographic Encoding and Referencing) project based on a simple but organized architecture of interdisciplinary and interoperable vector data.

As an endorsement from The American Association of State Highway (AASHTO) and Transportation Officials and the Federal Highway Administration (FHWA), for a better understanding of a more inclusive

urban and transport planning, whose participatory model can provide dialogue and operation, it is important to seek the concept of CSS as a recommended best practice in project development, providing a systematic and comprehensive approach from the beginning, from the planning stage to completion. As demand for new highways increases, many low-income neighborhoods are often considered in new highway design interventions. Although this issue has been recognized as part of environmental justice and CSS initiatives, no quantitative comparisons of the impacts of road construction on low-income households have been reported in the literature (DAVIS et al., 2009). In another study, the same authors analyzed different methods for modeling the optimized track alignments, incorporating road design restrictions and issues involving protected communities and populations. The authors also report that this process requires capturing all relevant data and problems, developing efficient solution algorithms, and working with accurate maps of the Geographic Information System – GIS (DAVIS et al., 2011).

Most streets focus only on mobility, sacrificing other functions, such as the environment, human health, preservation of local culture, and many other aspects that add value to society. Thus, because of this situation, Context-Sensitive Solutions, Place-Making, and Green Streets, are concepts that have evolved to better address issues about urban planning and projects (JIANG, 2016).

Complete Streets are defined as transportation infrastructures "designed to allow safe access for all users, including pedestrians, cyclists, drivers, and public transport passengers of all ages and abilities. Complete Streets are intended to make it easier for people to cross the street, walk to their destinations or cycle to work, and to help buses arrive on time, ensuring that it is still safe for people to walk from a bus stop to another". Green Street is a current term to define urban or rural projects aimed at improving the sustainability of the transport system, involving "many policies and practices that minimize the environmental impact." Furthermore, it addresses the site's existing hydrological and ecological functions, seeking to create localized rainwater systems and habitats using renewable building materials, green energy, and low-impact technologies. Besides being relatively new, these innovative approaches have promoted saving public money, suggesting a positive impact beyond the expectance (NELSON et al., 2022).

Place Making is a multifaceted approach to the planning, designing, and managing of public spaces, intended to inspire people to collectively reimagine and reinvent them as the heart of every community (Public Spaces Project, 2015). Thus, this concept intends to create public spaces that improve people's quality of life and achieve their goals, considering each local community's existing assets, inspiring characteristics, and potential. It can be described as sociable, adaptable, and context-specific (JIANG, 2016).

The architecture behind the participatory approach in CSS

The CSS approach has been demonstrated to be an excellent participatory model in the conception of urban and transport planning. It is combined with decision-making support methodologies in a process with actual data to carry out a comprehensive and concrete analysis, gains an application more efficient. In this sense, it is about establishing decision processes with multiple criteria and the AHP process for choosing the best alternatives (Figure 5).

Figure 5: Participatory meetings towards the proposal of the Interstate 269 in Millington-TN and Byhalia-MS in June, 2004. **Source**: Stich et al. (2011).

The concept of Multiple Criterion Decision Making, MCDM, reflects decision-making in a context with conflicting criteria. In other words, improving one criterion may harm another. Because of the complexity of obtaining a result that satisfies the numerous criteria indicated by a problem, the MCDM can be classified into two groups: Multiple Attribute Decision Making, MADM, and Multiple Objective Decision Making. MODM. From this perspective, urban and transport planning can fit both criteria, as it has numerous attributes (information) and diverse objectives.

The Analytic Hierarchy Process (AHP), which has been widely disseminated in the academy for a little over a decade, has also been used, and increasingly, as a tool to support decision-making in the private, government and third sector. In summary, the AHP is a structured methodology that can systematize and reflect on complex decisions, supporting group decision-making, with application in numerous situations and different sectors, based on mathematics and psychology, conceived by Thomas L. Saaty, in the 1970s (SAATY, 2000). In the AHP logic, the first step is to dissolve the problem into a hierarchy of more easily understood sub-problems so that they can be analyzed separately, and there will be no correct decision.

Incorporating Environmental Justice (E.J.) measures into automated models for highway projects is very challenging. Optimizing road alignments must incorporate road design constraints and issues involving protected communities and populations. The process requires capturing all relevant data and problems, developing efficient solution algorithms, and working with accurate maps from the Geographic Information System (GIS). Complex issues can also arise within this process which include: (1) a balance must be struck between the benefits to users of the facility and the effects on other community residents, (2) numerous effects (some positive, some negative) interact and must be balanced, (3) various population groups within the community may be affected differently in terms of combinations of effects, and (4) people vary in their preferences and opinions, so what is acceptable or even desirable for some may be unacceptable for others. As a result, various tradeoffs must be evaluated to present feasible results for all stakeholders. In addition, road agencies consider many road construction costs, the most significant being rights of way and construction costs, including earthworks and paving (DAVIS et al., 2009).

CONCLUSIONS

From the CSS perspective, the intervention of an urban transport infrastructure must necessarily bring multilateral benefits and not just for one sector. Therefore, the process must be understood and

discussed among specialists from different areas, including public participation. The Solution meets the needs of transport planning, public policies, transparency in the use of data, and rules for decision-making. In general, although there are occasional studies on sustainable mobility, CSS remains unknown in most developing countries, and there are still no specific projects that address all the issues proposed by the CSS. However, this situation can be changed since the CSS dialogues directly with different United Nations Sustainable Development Goals, which are currently fundamental factors in enabling the financing of large engineering projects.

CSS solves the right problem by broadening the definition of 'the problem' that a project should solve and by reaching a consensus with all stakeholders before the design process begins.

The literature and visited CSS initiatives in this investigation designed to revamp the local economy demonstrated the potential of the methods for minimizing environmental impacts while addressing policies for promoting welfare investments in transportation infrastructure for the local community. In practice, CSS has proven to be a powerful method to push transportation planning toward modernization and governance. In addition, it consolidated a tremendous tool for the transportation authority and decision-makers.

Regarding the technology, the CSS approach is likely to use GIS to couple multicriteria analysis methods to coordinate the decision-making process in transport. The computational resources required to address a CSS model nowadays is relatively simple. Therefore, the Solution does not require expensive software or hardware. Instead, CSS can be fully supported by open source and freely available GIS software.

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