

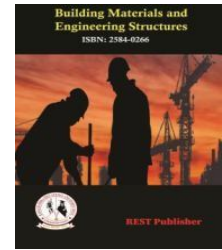


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Autonomous Vehicles and Their Impact on Transportation Systems an Integrated WASPAS Multi-Criteria Decision-Making Approach for Evaluating Safety, Efficiency, and Adoption Challenges

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Abstract: Autonomous vehicles (AVs) are poised to revolutionize transportation by offering increased safety, efficiency, and accessibility. This paper provides an overview of the current state of AV technology, its potential impacts on various aspects of transportation, and the challenges and opportunities associated with its adoption. AVs use a combination of sensors, cameras, and artificial intelligence to navigate and operate without human intervention. They have the potential to significantly reduce traffic accidents, as they can react faster than human drivers and are not susceptible to fatigue or distractions. Additionally, AVs can optimize traffic flow, reducing congestion and emissions. The adoption of AVs is expected to have far-reaching effects on transportation systems. For example, it could lead to a decline in car ownership, as people may prefer to use AVs on a pay-per-use basis rather than owning a vehicle. This could result in reduced demand for parking spaces and changes in urban planning. **Research significance:** AVs have the potential to significantly reduce traffic accidents, which could save thousands of lives each year. Research can help identify safety challenges and develop strategies to ensure AVs operate safely alongside human-driven vehicles. AVs could improve traffic flow, reduce congestion, and optimize routes, leading to more efficient transportation systems. Research can help quantify these benefits and develop algorithms to maximize the efficiency of AV fleets. **Method:** This method is highly effective in dealing with Multiple Criteria Decision Making (MCDM) challenges involving interval type-2 fuzzy sets with unknown values. In this study, the CRITIC and WASPAS techniques are combined to select a time and attendance software solution for a private hospital, both of which rely on fundamental mathematical procedures. **Result:** From the result High Personal vehicles is in the first rank whereas Autonomous vehicles has lowest rank.

Keywords: autonomous vehicles, Modeling transportation systems, sensors, AI, and connectivity, vehicle miles traveled.

1. INTRODUCTION

The rise of autonomous vehicles presents both challenges and opportunities for transportation policies. Challenges include regulatory frameworks, liability concerns, and impacts on employment. However, there are opportunities to improve road safety, reduce congestion, and enhance mobility access [3] Introducing autonomous vehicles is likely to have a significant influence on conventional transport modes and travel time. With the potential for increased efficiency and reduced congestion, autonomous vehicles could lead to a decline in traditional modes of transport such as private car ownership and conventional taxis. Additionally, autonomous vehicles could reduce travel time by optimizing routes, reducing traffic congestion, and potentially allowing for higher speeds with improved safety. However, these changes will depend on factors such as regulatory frameworks, infrastructure development, and public acceptance [4] Autonomous vehicles are expected to have a profound impact on cities, potentially reducing the need for parking spaces, improving traffic flow, and reshaping urban landscapes. However, they also raise concerns about increased congestion due to empty vehicles circling or cruising, as well as potential challenges in infrastructure adaptation and urban planning. [5] Understanding the travel behavior impact of autonomous vehicles is crucial for anticipating their societal effects. These vehicles could lead to changes in travel patterns, such as increased vehicle miles traveled (VMT) due to reduce costs and convenience, or a shift

towards shared mobility services. Additionally, autonomous vehicles may influence modal choice, with potential impacts on public transit ridership and active transportation modes. Studying these effects is essential for policymakers to prepare for the future of mobility effectively [6] Modeling transportation systems involving autonomous vehicles requires integrating factors like vehicle autonomy levels, user adoption rates, and infrastructure readiness. These models help assess impacts on traffic flow, energy consumption, and land use. They're essential for policymakers and planners to make informed decisions regarding regulations, infrastructure development, and urban planning strategies. [7] It involves predicting how societal trends, technological advancements, and regulatory decisions will unfold. Speculative scenarios could include shifts in urban development, changes in car ownership models, and new forms of mobility behavior, highlighting the need for adaptive policies. [8] Autonomous vehicles are distinct for their ability to operate without human intervention, relying on sensors, AI, and connectivity. This technology could transform urban transport systems by improving road safety, reducing traffic congestion, and enhancing mobility for the elderly and disabled. However, challenges such as regulatory hurdles, ethical dilemmas, and the potential for increased urban sprawl must be addressed. A comprehensive analysis should consider these factors to maximize the benefits of autonomous vehicles while mitigating their negative impacts on urban environments. [9] Evaluating a transportation system employing autonomous vehicles involves assessing factors such as safety, efficiency, accessibility, and environmental impact. Metrics like vehicle miles traveled (VMT), travel time, energy consumption, and equity should be considered. Additionally, public perception, regulatory compliance, and economic viability are crucial for determining the overall effectiveness and sustainability of the system. [11] As ownership may shift towards shared and on-demand services, individual vehicle ownership might decline. However, unoccupied VMT, where vehicles travel without passengers (e.g., searching for parking), could increase due to factors like empty trips and repositioning. Effective policies and incentives are crucial to mitigate these potential negative consequences and maximize the benefits of autonomous vehicles. [14]

2. MATERIALS AND METHOD

Alternative parameters: Autonomous Vehicles, Public Transport, Personal Vehicles, Ride-Sharing, Bicycles

Evaluation parameters: Reduced Traffic Congestion, Improved Safety, Privacy Concerns, Job Displacement

Public Transport: Public transport refers to a system of vehicles such as buses, trains, subways, and trams that operate on scheduled routes and are available for use by the general public.

Personal Vehicles: Personal vehicles refer to privately owned automobiles, motorcycles, or other modes of transportation used for individual or family travel. These vehicles are typically used for commuting, running errands, or recreational purposes and are not part of a shared transportation system like public transport.

Ride-Sharing: Ride-sharing, also known as carpooling or ride-hailing, refers to the practice of sharing a car ride with others, especially on a regular or daily basis, typically by people who travel to work or school in the same area. It can also refer to using a smart phone app to request a ride from a transportation network company like Uber or Lyft, where individuals can use their personal vehicles to provide rides to others for a fee.

Bicycles: Bicycles are human-powered vehicles with two wheels that are used for transportation, recreation, exercise, or sport. They typically consist of a frame, handlebars for steering, pedals for propulsion, and a seat for the rider. Bicycles are a popular and environmentally friendly mode of transportation in many parts of the world.

Improved Safety: Improved safety in the context of transportation refers to reducing the risk of accidents, injuries, and fatalities associated with travel. This can be achieved through various measures such as implementing stricter traffic laws, improving road infrastructure, increasing public awareness about safe driving practices, and advancing vehicle safety technologies.

Privacy Concerns: Privacy concerns in the context of transportation refer to issues related to the collection, use, and sharing of personal data from individuals using transportation services. This can include data collected from GPS devices, mobile apps, or other tracking technologies that may reveal information about a person's travel patterns, habits, or locations visited.

Method: The researchers introduce a novel approach, the extended WASPAS method, which extends the existing WASPAS technique. This method is highly effective in dealing with Multiple Criteria Decision Making (MCDM) challenges involving interval type-2 fuzzy sets with unknown values. In this study, the CRITIC and WASPAS techniques are combined to select a time and attendance software solution for a private hospital, both of which rely on fundamental mathematical procedures. An interesting finding is that different parameters in the WASPAS approach consistently yield different rankings, indicating the impact of various values across a range of selection issues. In this recent study, the researchers revised the core equations of their work and reevaluated how accuracy

is assessed using the WASPAS approach. Their analysis showed that calculating derivatives becomes notably challenging when considering predicted changes in the Weighted Point Method (WPM). As a result, they proposed an adjusted formula, which has been supported through its application in two different scenarios. Furthermore, they created computer tools that professionals can use to help them find optimal values and perform calculations for estimated variances. The IVIFS framework introduces a novel approach based on the WASPAS methodology, which incorporates IVIFS operators with slight modifications to the standard WASPAS approach, along with a novel mechanism for computing criteria and expert decision weights. The paper outlines innovative methods for determining expert and criterion weights by employing interval-valued intuitionist fuzzy data measures such as entropy, divergence, and similarity.

3. RESULT AND DISCUSSION

TABLE 1. Autonomous vehicles and their impact on transportation

	Reduced Traffic Congestion	Improved Safety	Privacy Concerns	Job Displacement
Autonomous Vehicles	90	2	3	2
Public Transport	92	1.5	4	3
Personal Vehicles	88	2.5	2	1
Ride-Sharing	91	2.2	3	4
Bicycles	89	1.8	3	7

Table 1 shows compare above values. Reduced Traffic Congestion: Public Transport has the highest score (92), followed closely by Ride-Sharing (91) and Personal Vehicles (88). Bicycles also score well (89), indicating that all modes contribute to reducing traffic congestion. Improved Safety: Public Transport has the lowest score (1.5), indicating it's perceived as the safest mode of transportation among the options listed. Bicycles have the second-lowest score (1.8), followed by Personal Vehicles and Autonomous Vehicles (both 2.0). Ride-Sharing has the highest score (2.2), suggesting it's perceived as having slightly higher safety concerns compared to the other modes. Privacy Concerns: Personal Vehicles have the lowest score (2), suggesting they're perceived as having the fewest privacy concerns among the options listed. Autonomous Vehicles and Bicycles tie for the second-lowest score (3), indicating moderate privacy concerns. Public Transport and Ride-Sharing have the highest scores (4), suggesting they're perceived as having the most privacy concerns among the options listed. Job Displacement: Personal Vehicles have the lowest score (1), indicating they're perceived as having the least impact on job displacement. Public Transport and Autonomous Vehicles tie for the second-lowest score (2), suggesting moderate concerns about job displacement. Ride-Sharing has a slightly higher score (4), indicating higher concerns about job displacement. Bicycles have the highest score (7), suggesting they're perceived as having the most significant impact on job displacement among the options listed.

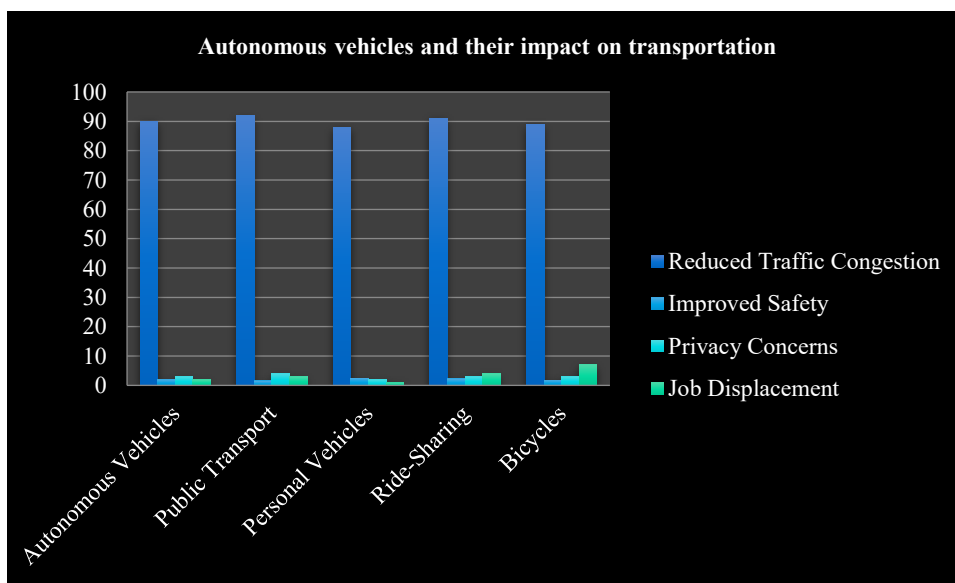


FIGURE 1. Autonomous vehicles and their impact on transportation

Figure 1 compare above values. Reduced Traffic Congestion: Public Transport has the highest score (92), followed closely by Ride-Sharing (91) and Personal Vehicles (88). Bicycles also score well (89), indicating that all modes

contribute to reducing traffic congestion. Autonomous Vehicles rank slightly lower (90), suggesting they have a significant but slightly lesser impact compared to public transport and ride-sharing. Improved Safety: Public Transport has the lowest score (1.5), indicating it's perceived as the safest mode of transportation among the options listed. Bicycles have the second-lowest score (1.8), followed by Personal Vehicles and Autonomous Vehicles (both 2.0).

TABLE 2. Weighted normalized decision matrix by WSM

Weighted normalized decision matrix			
0.24457	0.2	0.16667	0.125
0.25	0.15	0.125	0.08333
0.23913	0.25	0.25	0.25
0.24728	0.22	0.16667	0.0625
0.24185	0.18	0.16667	0.03571

Table 2 shows the weight normalized decision matrix. Alternatives: These are the different options or choices being considered. In this case, the alternatives are "Autonomous Vehicles," "Public Transport," "Personal Vehicles," "Ride-Sharing," and "Bicycles." Criteria: These are the factors or attributes used to evaluate the alternatives. Each column represents a criterion. For example, the criteria could be cost, environmental impact, convenience, and safety. Weights: These values represent the importance or priority assigned to each criterion. The weights are typically determined based on the decision-maker's preferences or the relative importance of the criteria. Normalized Scores: The scores in the matrix are typically normalized to ensure that they are comparable across different criteria. Normalization involves scaling the scores to a common scale, often between 0 and 1. Weighted Scores: The weighted scores are calculated by multiplying the normalized scores by the corresponding weights for each criterion. This step gives more weight to criteria that are more important, allowing for a more balanced comparison of alternatives. The weighted normalized decision matrix provides a structured approach to decision-making by quantifying and prioritizing criteria, which helps in selecting the most suitable alternative based on the decision-maker's objectives and preferences.

TABLE 3. Weight Normalized Decision Matrix by WPM

Weighted normalized decision matrix			
0.99452	0.94574	0.9036	0.8409
1	0.88011	0.8409	0.75984
0.98895	1	1	1
0.99727	0.96855	0.9036	0.70711
0.99175	0.92116	0.9036	0.61479

Table 3 shows the weight normalized decision matrix Normalized Decision Matrix: This is the matrix where each cell represents the performance of an alternative (row) on a criterion (column), normalized to a common scale. The values typically range from 0 to 1, with 1 indicating the best performance.

TABLE 4. Preference Score

Preference Score	WSM Weighted Sum Model	Preference Score	WPM Weighted Product Model	lambda	WASPAS Coefficient
0.73623		0.71467		0.5	0.36812
0.60833		0.56234			0.6615
0.98913		0.98895			0.98904
0.69645		0.61716			0.6568
0.62423		0.5075			0.56586

Table 4 shows the Preference Score WSM Weighted Sum Model: This model calculates the preference score by summing the weighted scores from the weighted normalized decision matrix. It is a simple additive model where the overall score for each alternative is the sum of the weighted scores for each criterion. WPM Weighted Product Model: This model calculates the preference score by multiplying the weighted scores from the weighted normalized decision matrix. It is a multiplicative model where the overall score for each alternative is the product of the weighted scores for each criterion. Lambda (λ): Lambda is a parameter used in the WASPAS (Weighted Aggregated Sum Product Assessment) method, which combines the WSM and WPM scores. It represents the degree of importance given to the WSM score relative to the WPM score. A value of 0.5 indicates equal importance to both scores. WASPAS Coefficient: The WASPAS coefficient is a combination of the WSM and WPM scores based on the lambda value. It is calculated as $\lambda * WSM + (1-\lambda) * WPM$. Interpretation: The preference scores

indicate the overall ranking of alternatives based on the two models. Higher scores indicate higher preference or better ranking. The lambda value in this context determines the balance between the additive and multiplicative models in determining the overall preference score.

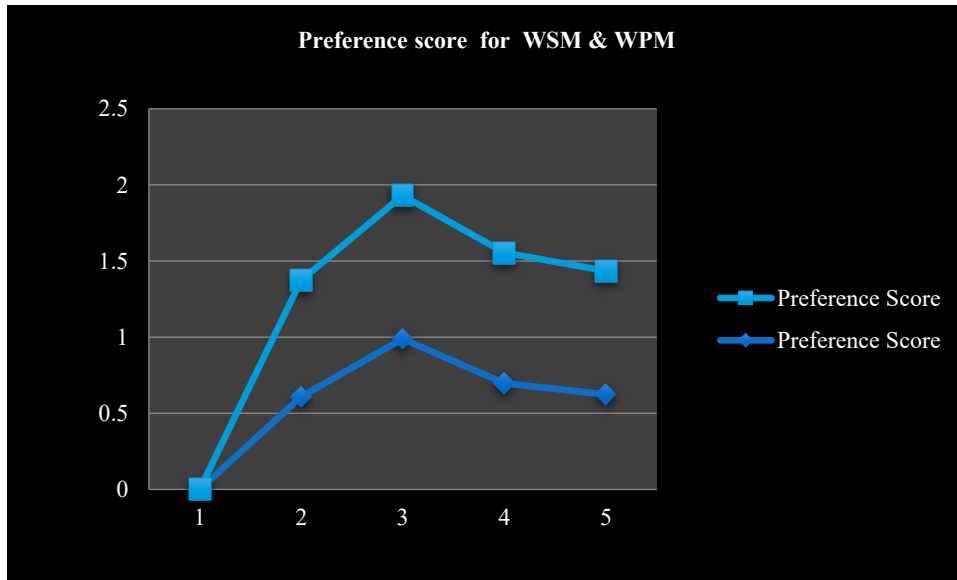


FIGURE 2. preference score

Figure 2 show the "Preference Score for WSM & WPM" compares the performance of five alternatives using two multi-criteria decision-making methods: Weighted Composite Model (WSM) and Weighted Product Model (WPM). The x-axis represents the five alternatives (from 1 to 5), while the y-axis shows the respective preference scores. From the graph, it can be seen that both methods follow a similar trend. Alternative 1 has the lowest score (close to zero) in both WSM and WPM, indicating weak overall performance. The scores for Alternative 2 increase significantly, showing a significant improvement. The highest preference score is observed for Alternative 3 in both models, reaching almost 2.0 for WSM and 1.0 for WPM, indicating that this alternative is the most preferred option under both evaluation techniques. After Alternative 3, the scores for Alternatives 4 and 5 gradually decrease, although they still maintain moderate performance levels. The similarity in trends between WSM and WPM indicates consistency in the rankings despite differences in calculation methods.

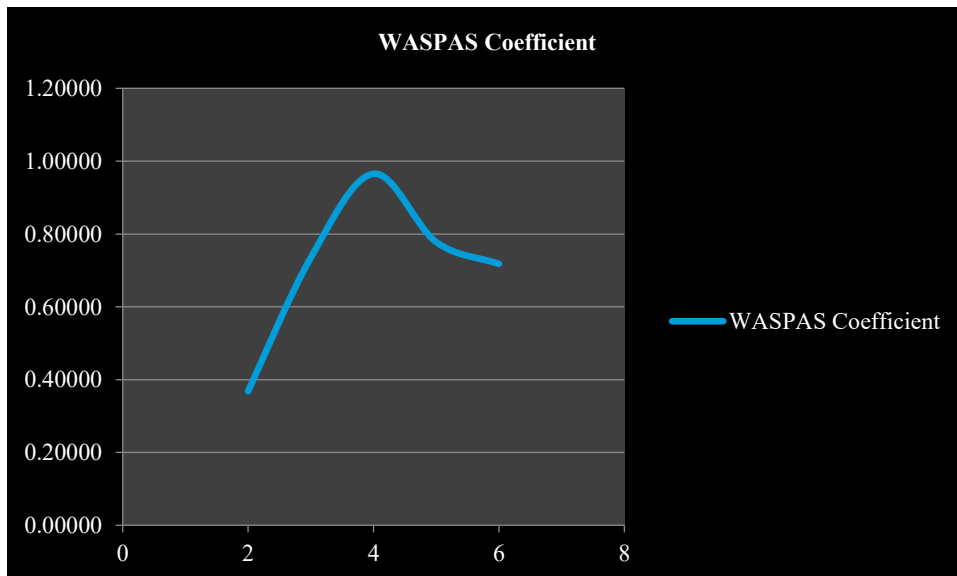


FIGURE 3. WASPAS Coefficient

Figure 3. show the relative performance of different alternatives using the WASPAS (Weighted Cumulative Product Assessment) method. The x-axis represents the alternatives, while the y-axis shows the calculated WASPAS coefficient values, which indicate the preference level of each option. From the curve, the coefficient initially starts at a moderate value (around 0.38) for the second alternative and then increases sharply. The highest

peak, near 0.95–1.00, is observed around the fourth alternative, indicating that this option has the strongest overall performance according to the WASPAS method. This peak suggests that the fourth alternative is the most suitable choice when both the additive and multiplicative assessment approaches are combined. After reaching the maximum value, the coefficient decreases slightly for the next alternatives, stabilizing around 0.70–0.75. Although these alternatives still show reasonable performance, they are less desirable compared to the first ranked option.

TABLE 5. Rank

RANK	
Autonomous Vehicles	5
Public Transport	3
Personal Vehicles	1
Ride-Sharing	2
Bicycles	4

Table 5 shows the provides a comparative assessment of five modes of transport based on overall performance criteria. The rankings range from 1 (best) to 5 (least effective), indicating their relative preference in the assessment. Private vehicles are ranked 1st, meaning they received the highest overall score of all alternatives. This indicates that they are considered the most favorable option in this assessment, according to selected criteria such as convenience, accessibility, flexibility, or efficiency. Ride-sharing is ranked 2nd, indicating strong performance and competitiveness. It is likely to benefit from cost-effectiveness, reduced traffic congestion, and the benefits of shared mobility. Public transport is ranked 3rd, reflecting moderate performance. While it may score well in affordability and environmental sustainability, it may have limitations in flexibility or convenience compared to higher-ranked options. Bicycles are ranked 4th. While they are environmentally friendly and cost-effective, factors such as limited speeds, distance restrictions, or infrastructure availability may have contributed to their low ranking. Finally, autonomous vehicles are ranked 5th, which represents the lowest overall rating in this analysis. This may be due to technological limitations, high costs, regulatory challenges, or limited accessibility.

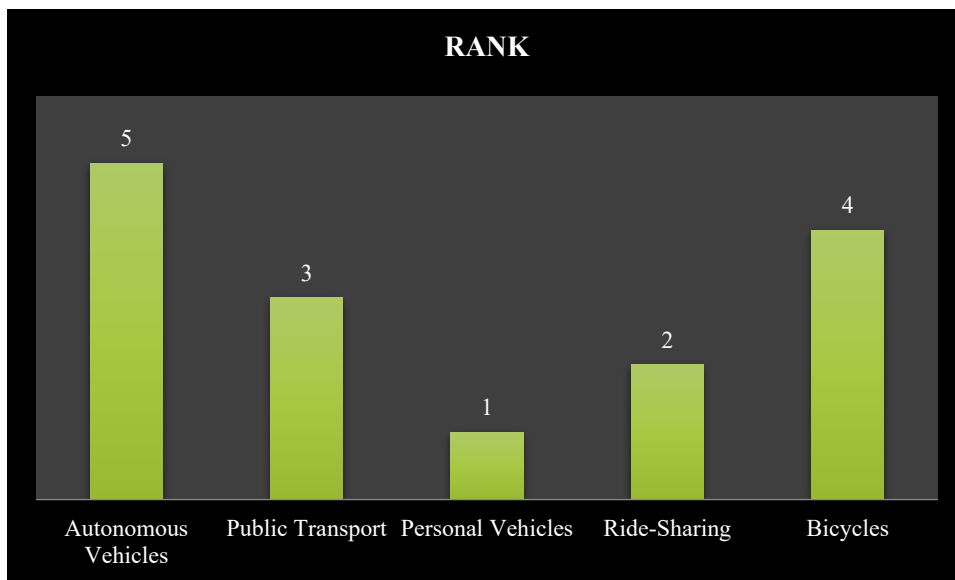


Figure 4. Rank

Figure 5 illustrates the Rank for Autonomous vehicles and their impact on transportation. Here the High Personal vehicles is in the 1st rank, ride sharing is in the 2nd rank, Public transport is in the 3rd rank, Bicycles is in the 4th rank, and, Autonomous vehicles is in the 5th rank.

4. CONCLUSION

Autonomous vehicles have the potential to reduce traffic congestion by optimizing routes and reducing accidents, their widespread adoption could lead to job losses in industries reliant on human drivers. Privacy concerns also loom large, as these vehicles collect vast amounts of data about their surroundings and passengers, raising questions about data security and surveillance. Despite these challenges, the development of autonomous vehicles continues to advance, with companies investing heavily in research and development. As these technologies

mature and become more widespread, policymakers and industry stakeholders must address these challenges to ensure that autonomous vehicles realize their full potential in transforming transportation for the better.

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