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Exploring The Impact of Intelligent Transportation Systems on Johannesburg Park Station and Transit-Oriented Development

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1 ABSTRACT

The efficacy of transportation systems generally relies on the pillars of intelligent transportation systems (ITS) and strategically located transit-oriented development (TOD). Moreover, this study examines the impact of ITS on the operations of Johannesburg Park Station within the framework of its TOD. The paper explores how it optimizes passenger flow within the station by leveraging various transportation modes, improved multimodal transfers, and enhanced TOD. The study uses a case study research design to investigate traffic management and passenger flow. Additionally, the study adopts both quantitative and qualitative research methods to gather relevant data. Interviews and questionnaires were used as tools to collect data. The preliminary findings reveal that it significantly contributes to Johannesburg Park Station by improving efficiency, accessibility, and the transportation network within the Gauteng region. The study concludes that it is data-driven and serves as a key tool for a thriving transportation ecosystem.

Keywords: Multimodal Transportation, Intelligent Transportation Systems, Johannesburg Park Station, Transit-Oriented Development, Spatial planning

2 INTRODUCTION

Contemporary cities, particularly in developing countries, face concerns regarding the efficacy and accessibility of public transport systems. The efficacy of transport systems generally rests on the pillars of intelligent transportation systems (ITS) and strategically positioned transit-oriented development (TOD). As such, there has been growing research on ensuring the sustainability of public transport systems (Balasubramaniam et al., 2017; Khazraeian and Hadi, 2019; Tran et al., 2023). This global shift has prompted various countries to adopt context-specific approaches to improving their transport systems. In China, for example, efforts have focused specifically on improving transportation infrastructure and advancing IT (Bešinović, 2020). These improvements have been driven by increased investment in the traffic management system, resulting in more efficient, convenient, safe, and intelligent public transport. The ultimate goal is to upgrade the current conventional cities into more intelligent, ecologically friendly, and economical cities.

On the other hand, Jimenez (2018) noted that many developing countries are falling behind in installing new transportation infrastructure in their cities, a concern that Gumbo et al. (2022) concurs with. To keep up with global advances in ITS technology, developing countries need to develop well-established transport policies to facilitate the rollout of innovative public transport systems (Gumbo et al., 2022). This would enhance the management and operation in a cost-effective manner. Similarly, Oeschger et al. (2020) argued that integrating new public transport modes could enhance accessibility and lead to modal shifts away from private vehicle use. To assess this potential for TOD, it is important to study these new modes in the context of access and egress trips to and from public transport, as several time-varying components affect optimal operation.

Haggag (2022),Hörcher & Tirachini (2021),& Ceder (2021) contend that previous studieshave investigated interdependent infrastructures as dynamic systems and connectivity for sustainability. Hörcher & Tirachini (2021) observe that empirical studies on ITS's role in enhancing public transport hub operations, specifically in TOD settings within the context of developing urban spaces, remain limited.To address this gap, the study proposes a hybrid ITS-TOD framework for up-and-coming urban hubs, where ITS data-driven tools (e.g., optimised AI scheduling) improve TOD diversity and density, at the same time accounting for local challenges such as spatial inequality. This framework complements Bešinović (2020)'s findings by incorporating resilience metrics for multimodal disruption in Gauteng.

3 RELATED WORK

Public transport system authorities require strategies to inform investments aimed at improving operations and services, both to retain current commuters and attract more users. Globally, there has been an increase in studies on TOD strategies and principles. The '6Ds' have been used to integrate urban development and transport by promoting higher density, encouraging land-use diversity, enhancing urban design, improving access to key destinations, reducing travel distances, and implementing demand management strategies. These seek to inform land types and densities along a transport corridor. Sung and Oh (2011) found that transit ridership is positively affected by the business and residential density and land-use mix index. Later, Ewing et al. (2021) evaluated the benefits of TOD and joint development throughout the United States. The study noted that a higher transit proximity premium of housing prices is most likely to occur in places with more mixed land use. While Ali et al. (2021) assessed the air quality across regions with urban areas. The study noted that transit-oriented development is linked with better air quality.

Modern communities face serious challenges in transportation systems, including accessibility, safety, and pollution. ITS has gained increasing attention and importance in TOD strategies and principles. By seamlessly integrating vehicles and sensing devices, cities can build smart, intelligent transportation systems. A study by Qureshi and Abdullah (2013) found that ITS is not limited to traffic research; it also provides hardware, positioning systems, sensor technologies, and services, and is implemented in navigation systems, air transport telecommunications, data processing, virtual operations, and systems. Due to such complexity, many developing countries are yet to fully realise the merits of ITS. Moreover, the implementation of ITS in these contexts is frequently constrained to pilot projects, hindering its ability to transform public transport systems at scale. In developed countries, local authorities are installing roadside infrastructure, such as cameras and sensors, to collect data on ecological and traffic conditions. These advances in ITS and Information and Communication Technologies (ICT) have led to sustainable transportation systems in these contexts (Guerrero-Ibáñez et al., 2018).

4 METHODOLOGY

This study adopted a mixed-methods approach, combining both qualitative and quantitative data collection techniques to yield a comprehensive understanding of the impact of Intelligent Transportation Systems (ITS) on Johannesburg Park Station and transit-oriented development (TOD). The study also included semi-structured interviews with four officials from CoJ's Department of Transportation, including two from the Johannesburg Road Agency, and 20 daily commuters. Both officials and commuters were selected purposively to ensure relevant and diverse perspectives. The quantitative data complemented the qualitative data from the interviews through structured interviews, which gathered comprehensive insights into the effectiveness and use of the ITS and TOD at Johannesburg Park Station. This methodology expedited a yield analysis of how ITS contributes to multimodal transfers and efficient passenger flow, supporting the overall efficacy of the transportation network and the TOD in Johannesburg.

5 RESULTS

5.1 ITS Impact on Passenger Flow and Multimodal Transfers in Johannesburg Park Station

The implementation of the ITS at Johannesburg Park Station has remarkably enhanced passenger flow within the public transit hub in the TOD vicinity of the station. The questionnaire data from 20 daily commuters indicated an average of 35% reduction in observed congestion during peak hours. 65% of participants reported that waiting times for multimodal transfers were under 5 minutes, compared to pre-ITS levels of 10-15 minutes (City of Johannesburg, 2023). 40% of daily commuters indicated that the nucleation of taxi ranks is the root cause of localised bottlenecks.

The public transit hub in Johannesburg Park Station includes Metrorail, the Wanderers long-distance taxi rank, the Bridge local Taxi rank, the Gautrain rail station, Gaubus, the MTN taxi rank, the public bus station (local, long-distance, and international), Rea Vaya, and E-hailing services (Uber and Bolt). Data collected from daily commuters indicate that rail transit hubs have reduced congestion during peak hours through real-time information displays and ticketing systems. Furthermore, the collected data indicate congestion during peak hours due to clustering of taxi ranks, as Johannesburg Park Station is the main TOD in the City of Johannesburg. The rail systems at Johannesburg Park Station form part of the ITS; these features streamline

passenger movement by providing timely updates on train (Gautrain and Metrorail) and bus schedules. This system allows commuters to make well-informed decisions, facilitating smooth passenger flow in the TOD vicinity of Johannesburg Park station.

Electronic ticketing has also improved the commuter experience, with users reporting faster, more predictable transit arrival and departure times, with mean reported boarding times decreasing from 4.2. minutes to 2.8 minutes. The seamless, comprehensive integration of various transport modes, enabled by the ITS, has also improved the efficiency of multimodal transfers, particularly at Johannesburg Park Station. The Johannesburg Park Station serves as a pivotal junction for multiple transportation services. The ITS solutions, such as coordinated transfer points and scheduling, have been instrumental in foreshortening transfer time between these modes. For clarity, Real-time coordination between Gautrain, Metrorail, MTN taxi rank, Bridge taxi rank, Rea Vaya, Metrobus, Gaubus, and e-hailing services ensures minimal wait time for passengers transferring between modes. Subsequently, the Johannesburg Park Station is a complex area; however, real-time directional signage helped commuters navigate the station with ease, reducing confusion and improving the overall effectiveness of multimodal transfers.

Additionally, interviews with CoJ and Johannesburg Road Agency officials, as well as daily commuters, have underscored the significant role of ITS in promoting a more user-friendly, accessible transit environment. The officials have adequately highlighted the strategic merits of ITS in-traffic management, noting that data-driven insights enable the optimization of service schedules and the allocation of services to meet passenger needs. Commuters, on the other hand, have indicated appreciation for the ITS, noting that the transition between various transport modes is now smoother and that they experience fewer significant delays. This synergy between TOD and ITS principles has not only enhanced the operational efficacy of Johannesburg Park Station but also contributed to a more integrated and sustainable urban transportation network in the CoJ.

5.1.1 Transport modes at Johannesburg Park Station ITS

The Johannesburg Park Station serves as an essential hub for various transport modes, all seamlessly integrated through ITS. This station is not only the biggest in Gauteng but also accommodates a variety of transport services including Metrorail for regional train travel, Gautrain for high-speed connections to key economic zones, Bus Rapid Transit (Rea Vaya) for swift urban commuters, taxis (The Bridge and MTN taxi rank) to connect to local townships and e-hailing services such as Uber and Bolt for flexible and shared rides. The ITS therefore simplifies efficient multimodal transfers by synchronizing schedules, providing transportation information and updates, and ensuring easy navigation via digital signage. This interconnection not only enhances the overall commuting experience but also fosters the use of public transportation by making it more accessible, user-friendly, and reliable. The following figures show images of various transportation modes at the Johannesburg Park station ITS.

Fig. 1: MTN Taxi Rank [Source: The Author (2025)]: The images show the MTN taxi rank during the day at peak hours.

Fig. 2: The Bridge Taxi Rank [Source: The Author (2025)]

Fig. 3: Wanderers Taxi Rank [Source: The Author (2025)]

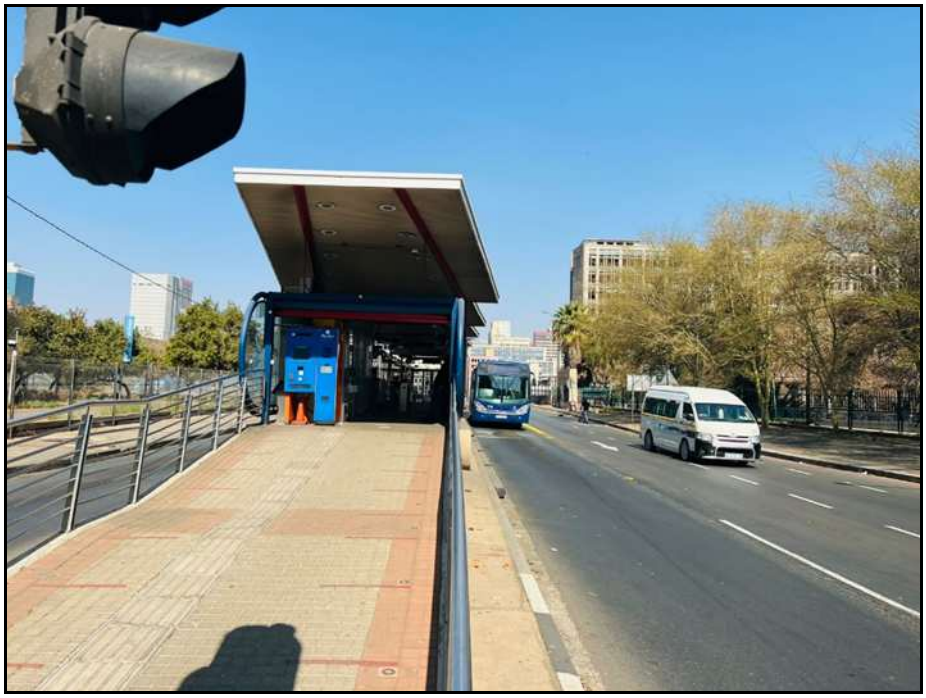

Fig. 4: Bus Rapid Transit (Rea Vaya) [Source: The Author (2025)]

There are three taxi ranks within the vicinity of Johannesburg Park Station's ITS. These are MTN Taxi Rank, The Bridge Taxi Rank, and Wanderers Taxi Rank as depicted in figures 1, 2, and 3, respectively. The MTN taxi rank is well known for connecting the local township with the city centre. These include taxis to areas in the north of Johannesburg, such as Alexandra township, Thembisa, Sandton, etc. The Bridge Taxi Rank connects daily commuters from the South of Johannesburg, such as Soweto, Zola, Dobsonville, and Meadowlands, to the Central Business District of Johannesburg. This network transports commuters into economic activities. The Wanderers Taxi Rank connects commuters to all the provinces in the country. It is also known to service international neighbouring countries such as Malawi, Zimbabwe, Botswana, etc. The ITS at Johannesburg Park Station also includes Bus Rapid Transit (BRT), in particular the Reya Vaya BRT, as depicted in the figure below.

The Rea Vaya is a swift transport that is the lifeblood of Johannesburg's Corridors of Freedom. As one of the first BRT systems implemented in Sub-Saharan Africa, Rea Vaya represents a strategic intervention to address the spatial fragmentation inherited from apartheid-era planning (Togo, 2016). It moves commuters from spaces like the Soweto corridors to the Johannesburg Park Station.

Fig.5: Metrorail [Source: The Author (2025)]

In the Johannesburg Park Station ITS, there are two rail transportation systems. These are the Metrorail and the Gautrain, as shown in Figures 6 and 7, respectively. The Metrorail is the lifeblood of Johannesburg Park Station. This rail transportation not only connects the 7 regions of Johannesburg, but also connects to the provincial regions such as Pretoria, Vereeniging, Germiston, and Springs. The Gautrain, on the other hand, is a high-speed rail offering an efficient and fast option for long-distance travel in the 3 metro cities. It connects OR Tambo International Airport, Pretoria, and Johannesburg. Complementing the Gautrain service is the Gaubus, a feeder and distribution network that extends the rail system's reach. It extends the train's reach, integrating rail and road transport.

Fig.6: Gautrain and Gaubus [Source: City of Johannesburg (2025)]

Figure 8 below is a Sankey diagram that uses width arrows proportional to the flow quantity to visualise how volumes move and distribute through various phases of the system. In this case, it specifically underpins

seamless integration at Park Station by indicating the scale of passenger transitions from primary rail lines to various last-mile transport modes.

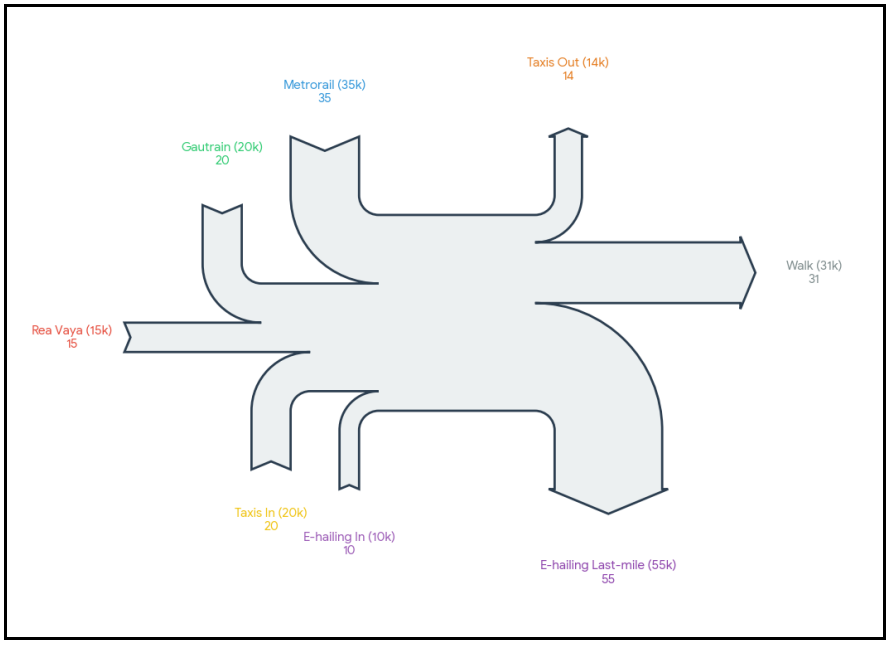

Fig.7: Passenger flow and seamless integration (Sankey Diagram)

5.2 ITS Contribution to TOD Success in Johannesburg Park Station

The ITS has adequately reinforced the success of the TOD at Johannesburg Park Station by improving the overall effectiveness and accessibility of the transportation network. The successful integration of the ITS solution, including the real-time tracking of Gautrain and Metrorail and automated ticketing, has developed a more elegant and user-friendly transit environment. However, the daily commuters indicate that the Johannesburg Park Station precinct is more transit-oriented. Moreover, interviews with daily commuters have indicated that these adjustments have provided them with public transportation options for daily commuting. Subsequently, supporting the core objectives of the TOD, which aim to adequately reduce the reliance on private transportation and encourage urban mobility and sustainable urban development. The data collected indicated that by enhancing the reliability and convenience of multimodal transportation options, the ITS has adequately contributed the role of promoting higher ridership levels and fostering a shift towards more sustainable commuting habits.

The implementation of ITS in Johannesburg Park Station has also catered to better urban development and land use in the vicinity. City of Johannesburg officials and daily commuters have also indicated that, with enhanced transportation services, the vicinity has experienced evident overcrowding and traffic congestion. This has emanated from business attractions and fostering the residential development within walking distance of the station. The principles of TOD align with the densification of ITS, which advocates mixed-use development integrating recreational, residential, and commercial spaces within a walkable distance of transit hubs. It is remarkable that this ITS has enabled efficient accommodation and management of increased passenger flow and volumes. This reinforces Johannesburg's transportation infrastructure to support the growing demand without compromising service quality. The economic vitality and liveability of the surrounding areas are also enhanced by improvements in ITS accessibility, reinforcing the TOD framework.

Subsequently, ITS has enabled a more data-driven approach to transportation management in Johannesburg and to the city's urban planning, both of which are vital to the long-term success of TOD initiatives. Passenger behaviour, transit system performance, and peak usage time have been analysed using real-time data collected via ITS applications; moreover, this data is processed by Gautrain, Gaubus, and Metrorail. Withal, urban planners and policymakers can utilise this available data to make sound, informed decisions about future development, service, and infrastructure investment. This proactive approach ensures transportation networks remain responsive and adaptable to the evolving needs of the urban population. By supporting sustainable and efficient transportation solutions, ITS has improved the operation of

Johannesburg Park Station and reinforced TOD goals, contributing to a more integrated and sustainable urban future for Johannesburg.

5.3 Commuters' Perceptions and Satisfaction with ITS

User feedback on the proficiency and reliability of ITS features at Johannesburg Park Station has been positive among daily commuters. The daily commuters have adequately demonstrated that the ITS provides the convenience of real-time information display, particularly at the Gautrain, Metrorail, Rea Vaya, and the local and long-distance buses. This feature has adequately minimised the stress and unreliability associated with waiting for public transportation. Daily users have also expressed positive sentiment toward the automated ticketing systems used by Gautrain, Gaubus, Metrorail, and Rea Vaya. This feature has also enhanced the efficacy of public transport, allowing commuters to swiftly purchase tickets and avoid long queues.

This study also reveals remarkable input through a comparison of satisfaction levels before and after the implementation of ITS, which improved commuters' movement and perceptions. Prior to the deployment of ITS, many daily commuters and CoJ officials reported frustration stemming from delayed services, inefficient transfer processes, and a lack of information. Recent data indicate that commuters have confidence in public transportation. Subsequently, the statistical analysis also supports a decrease in average waiting time for the next transportation and a reduction in the frequency of missing connections due to the provision of transportation information. The ITS has contributed to a more predictable and smoother commuting experience. These improvements have not only fostered higher ridership but also enhanced individual satisfaction by integrating e-hailing services, supporting the aims of TOD.

The key themes from the qualitative interviews with daily commuters have provided deeper insights into the lived experience of using the ITS at Johannesburg Park Station. Daily commuters have also indicated the value of planning journeys more effectively through real-time updates. It is noteworthy that the daily users reported that the ITS has also made it easier to coordinate transfers between different modes of transport, such as Rea Vaya, Gautrain, Gaubus, Metrorail, and taxis. Further, daily commuters noted that there are various transport modes at the Johannesburg Park Station ITS; these options offer diverse options for commuters.

Table 1 and Figure 8 below compare the Pre and Post ITS Data to demonstrate the historic performance and the current impact.

Metric	Pre-ITS (Baseline)	Post-ITS (Current)	% Improvement
Average Wait Time (min)	12.5	7.2	42%
Satisfaction Score (1-5)	2.8	4.1	46%
Daily Ridership (000s)	150	210	40%
Missed Connections (%)	18	7	61%

Table 1: Sources: Derived from questionnaire data and supplemented by Gautrain Annual Report (2024) and CoJ Transport Stats (2023)

6 DISCUSSIONS

The study's findings underscore the significance of ITS in enhancing TOD. In practice, the study found that the essence of ITS at Johannesburg Park Station has led to remarkable improvements in multimodal transfers and passenger flow. This implementation has reduced waiting times and increased commuters' satisfaction, thereby enhancing the appeal and efficiency of public transportation. The positive impact on urban development and land use around the station, particularly, underpins the strategic value of ITS in supporting the objectives of TOD. These practices paved the way for urban planners and policymakers in other cities seeking to adopt a similar system in their transportation planning. The collected data provides a nuanced understanding of how ITS contributes to the operational success of the transit hub and the TOD objective. The study underscores the significance of real-time data and automated systems in enhancing the reliability and convenience of public transport by boosting ridership and reducing reliance on private vehicles. Subsequently, the study identifies critical areas for future research, such as the long-term sustainability of ITS investments. By identifying and bridging the gap between practice and theory, this study proffers

invaluable contributions to the ongoing discourse on sustainable urban transportation and the role of modern technology in shaping future cities.

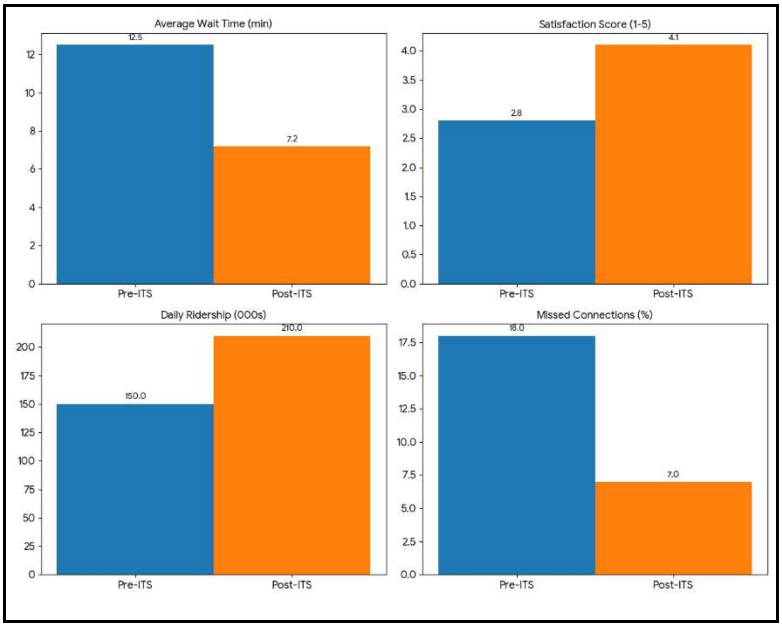

Fig.8 Pre and Post ITS performancemetrics at Johannesburg Park Station

The findings of this study make a significant contribution to both the theoretical understanding and the practical implementation of ITS in the context of TOD. The practical implications are vividly evident in the enhanced passenger flow and multimodal transfer efficiency at Johannesburg Park Station. This has adequately reduced waiting time and increased commuter satisfaction. For that, the study recommends integrating this initiative into land-use planning to enhance safety and security at Johannesburg Park Station, as the station is overcrowded and unsafe.

7 CONCLUSION

The study has highlighted the implementation of ITS at Johannesburg Park Station, as it has enhanced accessibility to the CBD and fostered the effectiveness of the TOD in the vicinity. The study has surfaced that ITS has not only improved multimodal transfer but has also optimised passenger flow. The ITS has significantly improved the integration of the vicinity of Johannesburg Park Station and enhanced the user-friendly public transportation network. The findings underscore the significance of data-driven solutions in contemporary urban planning, helping develop a more sustainable and efficient transportation ecosystem in Johannesburg. The study also revealed that the benefits of ITS are clear; however, it underscores the need for ongoing investments to improve safety and security in the vicinity, particularly in overcrowded areas. Withal, future research can focus on the long-term sustainability of ITS and its wider impact on sustainable urban development.

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