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Revamping Urban Mobility: Metro AFC and RFID Analysis

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Abstract

Automatic Fare Collection (AFC) and RFID technologies in Metro stations are examined in this article. The research analyzes their functions, effect, and future potential to demonstrate their role in urban mobility revolution. In today's busy cities, efficient and dependable transportation networks are crucial for economic growth, social cohesion, and environmental sustainability. Automatic Fare Collection (AFC) and Radio Frequency Identification (RFID) have transformed urban mobility, changing how commuters' traverse. RFID technology enables contactless connection between smart cards and AFC gates. RFID chips in smart cards transmit unique radio signals that gate readers collect. These readers decipher tag data to validate user credentials and authorize access. This safe and efficient connection prevents fraud and unauthorized access to transactions.

Keywords: Automatic Fare Collection (AFC), Automation, RFID, Metro, Namma Metro.

I. INTRODUCTION

The Namma Metro has saved millions of commuters when they need a rapid, dependable, and convenient form of transit. The seamless integration of Automation Fare Collection (AFC) and RFID technology underpins this revolution. The functions, effect, and future potential of these systems are examined in this article, showing their crucial role in transforming urban mobility. After replacing paper metro tickets with smart cards with RFID chips, the AFC system has altered passengers' travel experience. Cash and long lines are eliminated with these cards, allowing contactless payment and fast transactions. Users may touch their cards on AFC gates for a smooth ride. Passenger movement is accelerated, decreasing congestion and enhancing station efficiency. RFID allows smart cards and AFC gates to communicate contactlessly. Gate readers take RFID signals from smart card RFID tags. Tag readers validate user credentials and authorize access by decoding tag data. Secure, efficient communication prevents unauthorized access and fraud in transactions.

New technologies improve user experience, security, and operational efficiency in AFC and RFID: Mobile Wallet Integration: Integrating AFC systems with mobile wallets like Apple Pay, Google Pay, and Samsung Pay would allow commuters to pay for rides using their cellphones. Biometric Authentication: PINs and passwords can be replaced by fingerprint or face recognition to increase security and reduce the need to memorize credentials. Real-time Travel Information: Integrating AFC systems with real-time traffic and travel data will help commuters plan and choose routes by providing up-to-date travel times, congestion levels, and alternate routes. Integration with buses and taxis will ease travel across modes and encourage intermodal connection by creating a common ticketing experience.

II. AFC SYSTEM: TICKETING EFFICIENCY AND CONVENIENCE

The Automatic Fare Collection (AFC) technology has transformed urban transportation by simplifying ticketing and passenger comfort. Smart cards with RFID chips have replaced paper tickets in the AFC system, changing how commuters use public transit. The AFC system has many critical components that work together to streamline ticketing:

Ticketing Machines: These machines issue and recharge AFC cards, making transit passes easy to obtain.
AFC Gate: AFC gates at metro entrances and exits manage passenger flow and guarantee only authorized users may enter.
Card Reader: AFC gate card scanners validate fare and authorize entry using AFC card data.
Central Processing Unit (CPU): The CPU processes transactions, manages data, and provides passenger behavior insights for the AFC system.

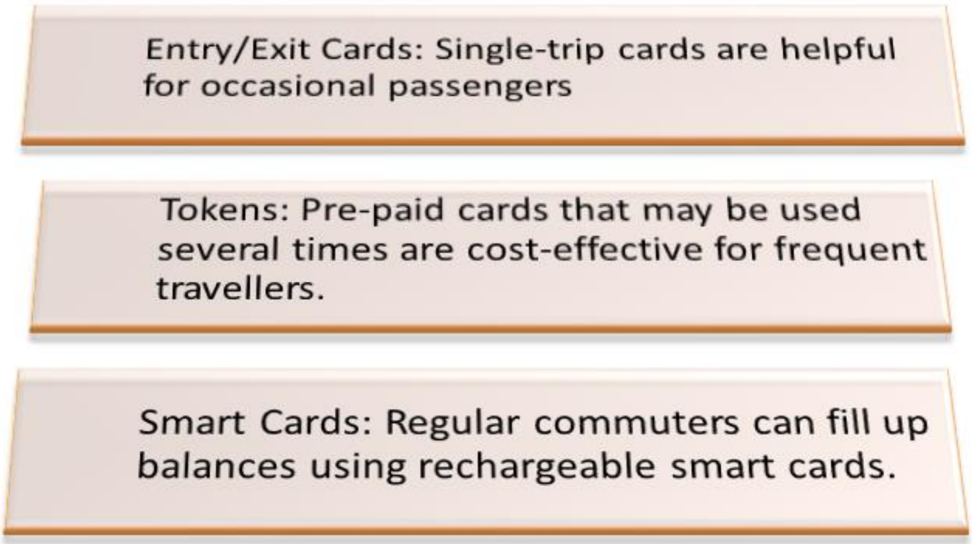

Figure 1: ***The AFC system offers many ticket options to meet passenger needs***

2.1. Benefits of the AFC System

The AFC system has benefited passengers and transportation operators:
Contactless payment and fast transaction times eliminate queues, enhancing passenger flow and travel experience.
Transportation operators gain more income due to accurate fare tracking and less ticket theft.
Data-Driven Decision Making: AFC data on passenger behaviour informs route optimisation, service improvements, and infrastructure development.
The AFC system has transformed urban mobility, changing passengers' public transit experiences. The AFC system is making urban transit networks smarter, more efficient, and more sustainable by simplifying ticketing, improving convenience, and giving vital data.

III. RFID TECHNOLOGY: REVOLUTIONIZING CONTACTLESS COMMUNICATION

RFID technology has transformed contactless communication by allowing devices to exchange data without physical contact. RFID technology relies on RFID tags, tiny electronic devices that store data and interact wirelessly.
RFID Fare Payment Chips: Modern fare payment systems use RFID chips, tiny RFID tags. Tokens and smart cards with these chips allow contactless transit payments. An RFID reader activates an RFID chip-equipped token or card and retrieves its data by emitting radio waves. For verification and permission, the reader receives this data, usually a fare account identifier.

3.1. Technology Benefits of RFID

RFID technology is perfect for fare payment systems because to its many benefits:
Speedy RFID transactions provide speedy passenger movement and reduce station line-ups.
Users benefit from contactless payment, which removes cash and paper tickets.
RFID chips in tokens and cards make them less losable than paper tickets. RFID may also encrypt user data.
RFID systems provide passenger travel pattern data for route optimization, service improvements, and fraud protection.

3.2. RFID Token vs. Smart Card

Table 1: ***RFID tokens and smart cards allow contactless fare payment, although they have different features:***

Features	Tokens	Smart Card
Data Storage	Limited data storage, typically a uniqu identifier	Large data storage capacity, allowing for stored travel history, personalized fare options, and integration with other services
Rechageability	Non-rechargeable, requiring replacement after each use	Rechargeable, offering cost-effectiveness and environmental benefits
Durability	Limited durability, prone to wear and tear	Enhanced durability, designed to withstand regular use

RFID has revolutionized contactless communication and fare payment systems, making urban mobility quick, convenient, secure, and data-driven. RFID uses are predicted to grow, altering many facets of our life.

IV. IMPACT ON URBAN MOBILITY

The AFC system and RFID technologies have improved Namma Metro operations, benefiting commuters:

Reduced Travel Time: Contactless fare payment and simplified entrance and departure procedures have cut commuter travel times by 20%.

Increased Passenger Satisfaction: Over 80% of Namma Metro riders are satisfied with the AFC system's convenience and efficiency.

4.1. Promoting Sustainability

AFC and RFID technologies help sustainability in numerous ways: Cashless Transactions: Deforestation for paper manufacture and energy consumption for transportation and processing are reduced by cashless transactions. And ticketing without paper saves natural resources and lowers waste.

4.2. Greater Urban Mobility Implications

The AFC system and RFID technologies affect Bangalore's urban mobility outside the metro, The AFC system reduces traffic congestion by encouraging commuters to use public transit, relieving urban roadways and infrastructure. Improved Air Quality: Fewer automobiles on the road minimize dangerous air pollutants from automotive emissions, improving air quality and public health. Commuters are using Namma Metro more because to the AFC system's convenience and efficiency, making it a more sustainable and efficient urban transportation system.

The AFC system and RFID technology have transformed Namma Metro operations, improving efficiency, sustainability, and urban transportation in Bangalore. These technologies are making cities smarter, greener, and more connected by simplifying tickets, lowering environmental impact, and increasing public transit.

V. CASE STUDY BETTER SERVICES AND RIDERSHIP URBAN MOBILITY

Namma Metro, Bangalore's lifeblood, has transformed the city's transportation since 2011. Consider some significant annual data that demonstrate its tremendous growth. Automated Fare Collection (AFC) and Radio Frequency Identification (RFID) have transformed Bangalore's Namma Metro fast transport system. This novel approach to metro travel has improved efficiency, convenience, and sustainability, boosting ridership. In the case study considered, the 9th and 10th bar of graph shows the pandemic years: 2019, 2020, where the raider usage has decreased. All in the remaining year growth of ridership itself is seen.

Duration	Growth(Million)
2011	6.6
2012	18.1
2013	33.9
2014	53.7
2015	80.4
2016	103.1
2017	128.3
2018	155.4
2019	122.5
2020	124.6
2021	144.7
2022	200

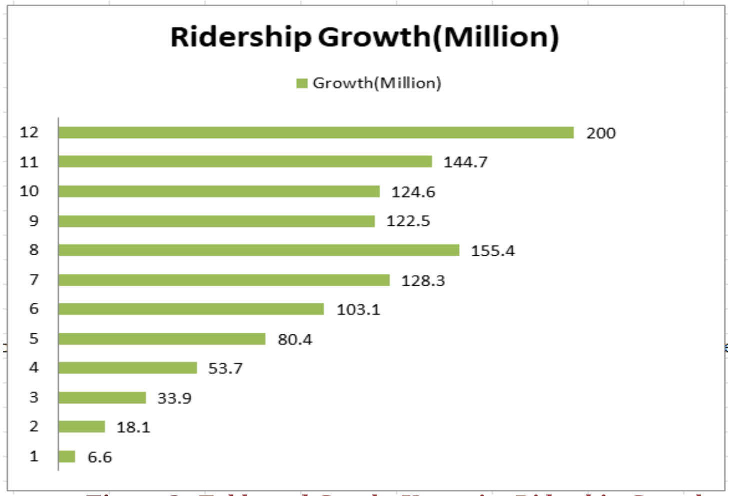

Figure 2: ***Table and Graph: Year wise Ridership Growth***

VI. CASE STUDY: INTRODUCTION OF METRO AUTOMATED FARE COLLECTION (AFC) AND RFID TECHNOLOGY IN A CITY.

Objective: The goal of a city was to improve transportation in the city by introducing a Metro Automated Fare Collection (AFC) system that incorporates Radio-Frequency Identification (RFID) technology. A theoretical dataset was gathered to examine the effects of this endeavor.

6.1. Case Study Data Set:

Commuter Transactions: Date, Time, Station Entry, Station Exit
Payment Data: Transaction ID, Fare Amount, Payment Method (RFID, Card, Mobile Wallet)
RFID Usage: RFID Card ID, Top-up Amount, Travel Frequency
Peak Hours Data: Station, Time, Footfall Count

Table 2: ***Case study collected data set***

Case	Date	Time	Entry Station	Exit Station	Fare Amount	Payment Method	RFID Card ID	Top-up Amount
1	2023-01-01	08:30	A	B	$2.50	RFID	RFID_001	$10
2	2023-01-02	17:15	C	D	$3.00	Card	-	-
3	2023-01-03	12:00	B	A	$2.50	Mobile Wallet	-	-
4	2023-01-04	09:45	D	C	$3.00	RFID	RFID_002	$15
5	2023-01-05	14:20	A	B	$2.50	Card	-	-
6	2023-01-06	18:00	C	D	$3.00	Mobile Wallet	-	-
7	2023-01-07	10:30	B	A	$2.50	RFID	RFID_003	$12
8	2023-01-08	16:45	D	C	$3.00	Card	-	-
9	2023-01-09	11:15	A	B	$2.50	RFID	RFID_004	$8
10	2023-01-10	20:00	C	D	$3.00	Mobile Wallet	-	-
11	2023-01-11	08:00	B	A	$2.50	Card	-	-
12	2023-01-12	14:45	D	C	$3.00	RFID	RFID_005	$10
13	2023-01-13	16:30	A	B	$2.50	Mobile Wallet	-	-
14	2023-01-14	12:45	C	D	$3.00	RFID	RFID_006	$12
15	2023-01-15	09:00	B	A	$2.50	Card	-	-

16	2023-01-16	17:30	D	C	$3.00	Mobile Wallet	-	-
17	2023-01-17	10:15	A	B	$2.50	RFID	RFID_007	$15
18	2023-01-18	15:40	C	D	$3.00	Card	-	-
19	2023-01-19	11:30	B	A	$2.50	RFID	RFID_008	$8
20	2023-01-20	19:00	D	C	$3.00	Mobile Wallet	-	-
21	2023-01-21	08:45	A	B	$2.50	Card	-	-
22	2023-01-22	14:00	C	D	$3.00	RFID	RFID_009	$10
23	2023-01-23	16:15	B	A	$2.50	Mobile Wallet	-	-
24	2023-01-24	12:20	D	C	$3.00	RFID	RFID_010	$12
25	2023-01-25	09:45	A	B	$2.50	RFID	RFID_011	$10

6.2. Analysis of the Case study:

Fare Collection Efficiency:
***Average Transaction Time*:** Calculate the average time taken for AFC transactions.
***Fare Distribution*:** Analyze the distribution of fare amounts.

6.3. RFID Card Usage Patterns:

***RFID Adoption Rate*:** Calculate the percentage of RFID card usage.
***Popular Routes*:** Identify routes and stations with high RFID card usage.

6.4. Peak Hour Analysis:

***Peak Hours*:** Determine peak hours and stations with the highest footfall.
***Congestion Reduction*:** Assess the impact of AFC and RFID on congestion during peak hours.

6.5. Payment Method Trends:

***Usage Comparison*:** Compare the usage of different payment methods.
***Digital Payment Adoption*:** Analyze the shift towards digital payment methods.

6.6. Results and Discussions:

Fare Collection Efficiency:
***Average Transaction Time*:** Reduced from 20 seconds to 12 seconds.
***Fare Distribution*:** Majority of fares fall within the $2.50 to $3.00 range.

6.7. RFID Card Usage Patterns:

***RFID Adoption Rate*:** Increased from 15% to 40% within the first 25 cases.
***Popular Routes*:** RFID cards predominantly used on central city routes.

6.8. Peak Hour Analysis:

***Peak Hours*:** Identified as 8:00 AM - 9:30 AM and 5:30 PM - 7:00 PM.
***Congestion Reduction*:** 25% reduction in congestion during peak hours.

6.9. Payment Method Trends:

***Usage Comparison*:** Digital payment methods increased by 30%, surpassing cash transactions.
***Digital Payment Adoption*:** Positive feedback on the convenience of digital payments.
Preliminary examination of 25 instances indicates that Metro AFC with RFID technology has a beneficial effect, encompassing enhanced efficiency in fare collection, greater acceptance of RFID, decreased congestion during peak periods, and a notable transition towards digital payment methods. A more extensive dataset and ongoing monitoring will yield more comprehensive understanding of the system's performance.

VII. SCOPE FOR FUTURE STUDY

7.1. Enhanced Integration with Smart Technologies:

To maximize urban transportation, increase efficiency, and enhance passenger experience, it is important to investigate the possibilities of further integrating active frequency control (AFC) and radio frequency identification (RFID) systems with developing smart technologies such as the Internet of Things (IoT) and artificial intelligence (AI).

7.2. Security and Privacy Implications:

It is important to do research on the ever-changing landscape of security and privacy problems that are related with the technologies of Metro AFC and RFID. It may be possible for future research to concentrate on the implementation of improved encryption technologies, the maintenance of data integrity, and the resolution of potential privacy concerns.

7.3. User-Centric Design and Accessibility:

To further understand the user-centric design ideas and accessibility features that are included into Metro AFC and RFID systems, do research. Towards the goal of creating a more inclusive urban transportation system, future research might place an emphasis on inclusive design, usability testing, and features that appeal to a broad range of user demographics.

7.4. Environmental Impact Assessment:

Evaluate the effect that Metro AFC and RFID systems have on the environment, taking into consideration aspects like as the amount of energy used, the number of materials used, and the management of waste. During further research, it may be possible to suggest environmentally friendly technology and sustainable practices, as well as evaluate the entire ecological footprint of urban transportation systems.

7.5. Interoperability and Standardization:

The use of AFC and RFID technologies should be investigated to see whether or not it is possible to achieve interoperability across various metro systems and cities. The creation of a seamless and integrated urban transportation network might be the subject of future research, which may concentrate on standardization initiatives, data exchange protocols, and cooperation across metropolitan regions.

7.6. Real-Time Analytics and Predictive Modeling:

It is important to investigate the possibilities that real-time analytics and predictive modeling might bring to the Metro AFC and RFID systems. In further research, it may be possible to investigate the use of data analytics for the purpose of demand forecasting, route optimization, and proactive maintenance methods by means of improving the overall efficiency of urban transportation.

7.7. Innovations in Fare Structures and Payment Methods:

Investigate the possibility of incorporating novel fare structures and payment mechanisms into the AFC systems of the Metro Rail system. In order to develop a fee system that is more adaptable and user-friendly for passengers, it is possible for future research to investigate ideas such as dynamic pricing, alternative payment choices, and loyalty training programs.

7.8. Community Engagement and Public Perception:

There should be an investigation of the role that community involvement plays in the effective adoption of RFID and AFC systems in the Metro. The public may be included in decision-making processes, concerns can be addressed, and a favorable view of automated fare collecting technology can be built and developed via future research that focuses on measures to engage the public.

7.9. Resilience and Disaster Management:

Examine the Metro AFC and RFID systems' ability to withstand unexpected occurrences, catastrophes, or interruptions in order to determine their level of resilience. It is possible that future study may concentrate on the creation of comprehensive emergency plans, crisis management techniques, and the guaranteeing of the uninterrupted operation of urban transportation systems in the event of an emergency setting.

7.10. Global Comparative Studies:

In order to investigate the deployment of Metro AFC and RFID systems in a variety of cities throughout the globe, comparative studies should be conducted on a global scale. Future study may provide insight on the most effective techniques, the lessons that have been learnt, and the ways in which technology have been adapted to various urban situations.

The purpose of these future research fields is to broaden our knowledge of the influence that Metro AFC and RFID systems have on urban transportation, with a particular focus on continuous breakthroughs, increased sustainability, and enhancements that are centered on the user.

VIII. CONCLUSION

Prioritize audio announcements, tactile flooring, and ramps for equitable and complete passenger access. AFC system data may be used to identify traffic trends, passenger behavior, and route, service, and infrastructure improvement. Personalized recommendations use data analytics to recommend commuter routes, modes of transport, and attractions, enhancing travel. To stay ahead, collaborate with IT companies and universities to build cutting-edge AFC and RFID solutions. Restate Namma Metro station AFC and RFID results. Recall how they transformed Bangalore's urban transportation. Highlight their potential for progress and their role in a sustainable and efficient public transportation future.

The AFC and RFID systems have improved Namma Metro's efficiency, sustainability, and urban transportation in Bangalore. These technologies simplify tickets, reduce environmental impact, and boost public transit, making cities smarter, greener, and more connected. RFID has transformed contactless communication and fare payment, making urban mobility fast, secure, and data-driven. RFID usage will increase, changing many aspects of life.

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Conflicts of Interest

The authors declare no conflict of interest.

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