

Comparative Analysis of Personal Rapid Transit System with Thermoplastic Material for Interconnecting Metro Station with Airport

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Abstract

PRT (Personal Rapid Transit systems) open a slew of new possibilities for solving airport-related transportation issues, both on the ground and in the air. For use in airport applications, the advantages and disadvantages of this mode of transportation are contrasted. An implementation of the ULTra Personal Rapid Transit system to assist passenger and staff vehicle squares at Heathrow is used to showcase the work. The ULTra infrastructure's compact size and flexibility allow it to utilize tunnel side bores and integrate with the complex central terminal area in an unexpectedly straightforward manner. In comparison to present buses, detailed comparisons demonstrate a reduction in travel time and a reduction in operational costs. The glass/PP face sheets were produced using a single diaphragm forming procedure. Microstructural examination of the face sheets proved that this method produces excellent consolidation. The face sheets and core material were adherently joined and tested to verify the model. The body panel failed due to an adhesive failure when the stress reached 11.7 kN. The American Public Transportation Association's (APTA's) requirements for the body panel's static loading were met. A traditional bus with an aluminum covering and supporting steel bars showed excellent weight savings of more than 55% as compared to the thermoplastic composite body panel. The research demonstrates that such modes of transportation are ideally suited to land-side airport uses. A summary of potential benefits for airside operations is also provided.

Keywords: Urban transportation, Personal rapid transit, Podcar, ULTra PRT, Intelligent transport system, Thermoplastic materials

INTRODUCTION

PRT, commonly referred to as a pod car, is a form of public transportation that makes use of little autonomous vehicles that travel over a system of specially designed guide ways. PRT falls under the category of automated guide way transit (AGT), which encompasses everything from massive vehicles to modest subway networks (Figure 1). PRT is designed for individuals or small groups, with each vehicle carrying 3 to 6 passengers at most. All stations are located on sidings, and there are several merge/diverge junctions across the network structure of the guide ways. This makes it possible to go nonstop from point A to point B without using any intermediate stations. One person compared the point-to-point service to a cab. Most public transit systems operate along pre-planned routes and carry passengers in groups. It is not perfect [1–3]

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Time is wasted by passengers waiting for the next train, making detours to get there, pausing for others going somewhere else, and navigating frequently unclear or erratic schedules. Huge items moving slowly or quickly can impair the environmental advantages of public transportation while also slowing down other cars. Personal rapid transportation system attempts to eliminate these wastes by transporting small groups of people in automated vehicles on predetermined tracks in an unending loop. Travelers must be able to board a pod as soon as they arrive at a station, and if the rail network is large enough, they should be able to travel directly to their destination without stopping.



Figure 1. An ULTra PRT vehicle [1].

Manufacturing of Thermoplastic Body Pan Segment

A body panel in cross-section showing the pan portion created (Figure 2). It has exterior and inner face sheets made of Glass/PP woven tape, a PP honeycomb core inside the pan portion section, and PU foam stuffed inside the cavity. Hot-melt glue was used to bind the face sheets to the PP honeycomb core. The pan segment's manufacturing process is. The following are the procedures for creating the body panel: Making the glass/PP tape and weaving, making the interior and exterior face sheets, bonding the honeycomb core to the interior panel, filling the rounded corners with polyurethane foam, and bonding the exterior flat panel to the interior panel and core are all examples of steps in the manufacturing process. If the core is machined to match the shape of the pan cavity [2].

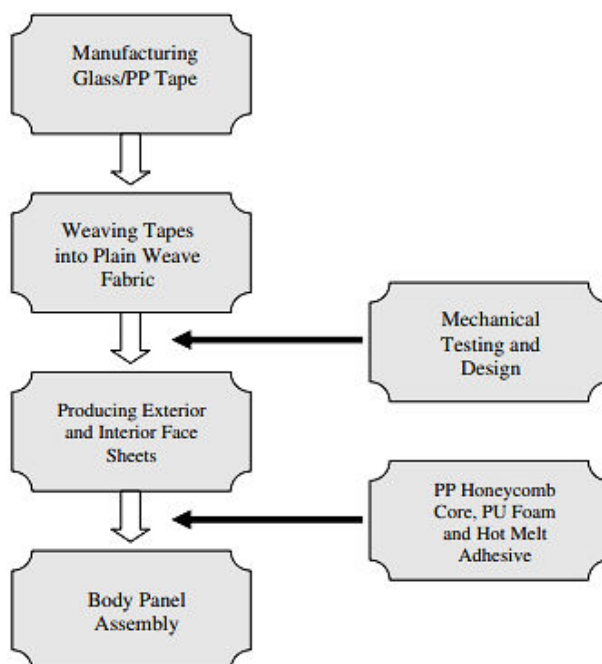


Figure 2. Steps of manufacturing of thermoplastic body pan segment [2].

By using a hot-melt impregnation procedure, glass/PP tape with a fibre content of 67% weight (42% volume) was created [4–5]. An outside source shaped the tapes into a plain weave architecture. The plates made from four layers of the glass/PP tape had their mechanical parameters, such as tensile modulus and strength, flexural modulus, and strength, tested. At the bottom chamber, where the woven tape was placed, an 85 kPa vacuum was applied. Along with the vacuum pressure, high-pressure air was pumped into the top chamber to create a pressure of 344 kPa, which was used to apply a consolidating force to the prep-reg through the flexible silicon diaphragm [2]

STUDY AREA

Airport Metro station, Nagpur (21.08720, 79.06342) to Dr. Babasaheb Ambedkar International Airport, Nagpur (21.09028, 79.05463) situated 8 km Southwest of City part of Nagpur (Figure 3).

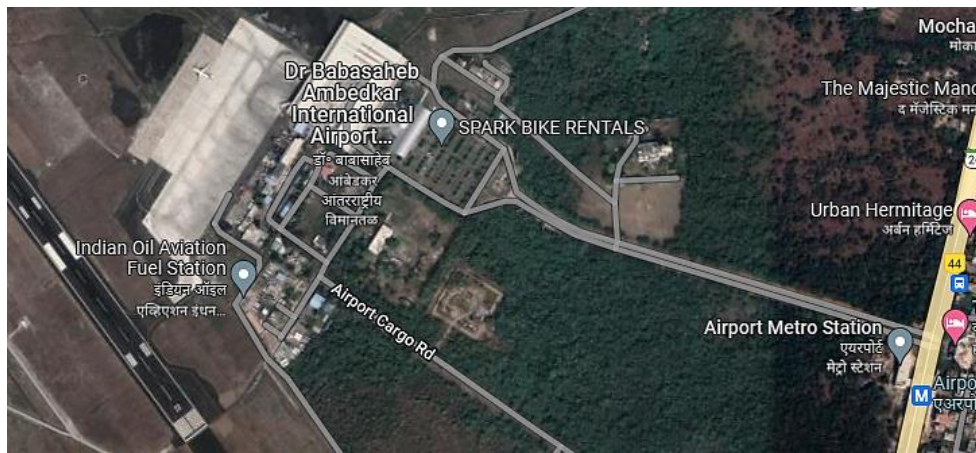


Figure 3. Study Area.

METHODOLOGY

The methodology for comparative analysis of personal rapid transit system is as follows. To identified parameters and factor for comparative analysis of personal rapid transit system are Feasibility, Safety, Comfortness, Level of service, Time Consumption, Capacity and Revenue [6]. After collecting data for each parameter, the comparative analysis between existing service and personal rapid transit system. After analysis result and conclusion is calculated (Figure 4).

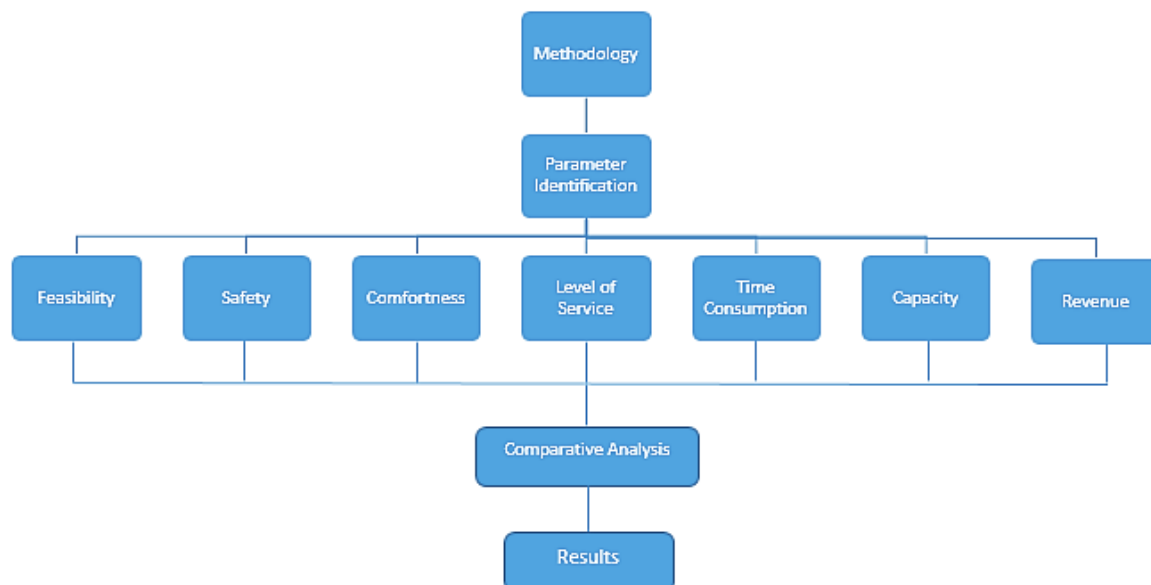


Figure 4. Flow chart of Methodology.

DATA COLLECTION

Feasibility

Operational Feasibility

Operative feasibility of shuttle bus service and PRT system is compared. The parameters such as headway, speed, average occupancy, average trip length, route length. To compare parameters difference is calculated of each parameter [7–8]. The data of shuttle bus is collected from NMC transport department. The Difference between headway is nearly 4 and half minutes, speed difference is 15 kmph, average occupancy is 28.7, average trip length and route length difference is same (Table 1).

Table 1. Operational feasibility for existing shuttle Bus services and PRT system [1]

	Shuttle Bus Service		Difference	Shuttle Bus Service
Operational	Headway	5 m	3s	297s
	Speed	45 kmph	30 kmph	15 kmph
	Average Occupancy	32	3.3	28.7
	Average Trip Length	2 Km	2 Km	0
	Route Length	2 Km	2 Km	0

Safety

One of the primary causes of unintentional deaths worldwide is traffic accidents. Any misalignment on the road is dangerous for the driver, the vehicle, the business, and the client. The accident data is collected near Nagpur airport from 2015 to 2021. The data is collected in three-part numbers of accident, number of deaths and number of injured of each mode of transport near Nagpur airport. The data is collected from DCP traffic police office as well as NMC transport department [9–10]. The data indicate the safety of passenger and personal rapid transit system having zero numbers of accident (Table 2).

Table 2. Accident data for existing services and PRT system

	Nagpur airside accident Data 2019-21			PRT accident Data 2019-21			Difference		
	Accident	Death	Injured	Accident	Death	Injured	Accident	Death	Injured
2015	5	1	8	0	0	0	5	1	8
2016	6	2	7	0	0	0	6	2	7
2017	4	1	5	0	0	0	4	1	5
2018	5	1	6	0	0	0	5	1	6
2019	6	3	9	0	0	0	6	3	9
2020	1	0	2	0	0	0	1	0	2
2021	4	2	6	0	0	0	4	2	6

Comfortness

The experience of transportation passengers must include comfort. Crowding can dramatically reduce passenger comfort, impede the delivery of services, and discourage people from using public transportation. The data is collected from the survey of passengers of shuttle bus service that is connecting airport metro station to airport. After collecting data from passengers, it is divided into three parts that is comfortable, uncomfortable and extremely uncomfortable. The parameters taken that are seat types, maintenance, travel time, air condition, air quality, lighting, and visual comfort. Most of the passengers and staff of airport having issue with existing service regarding timing, fare, condition of vehicles etc. The data indicates passenger's review (Table 3).

Level of Service (LOS)

To link the standard of traffic service to a specific flow rate, a concept known as Level-of-Service (LOS) of a traffic facility was developed. HCM proposed the term "Level-of-Service" to describe the

standard of quality that can be obtained from a location under various operation parameters and traffic volume. HCM defines LOS as a letter that specifies a variety of operational circumstances for a specific type of facility. HCM defines six LOS letters, A through F, with A representing the highest level of service and F representing the lowest. These definitions are based on the facility's effectiveness measures. Speed, travel time, density, delay, and other metrics are commonly used to assess effectiveness. Each LOS level will have its own service volume. A service volume or service flow rate is the maximum number of cars, passengers, or the like that can be accommodated by a specific facility or system under specific conditions at a specific LOS (Figure 5).

Table 3. Comparison of comfortness between shuttle bus service and PRT system

Comfortness Parameters	Shuttle Bus	PRT System
Types of seat	Uncomfortable	Comfortable
Maintenance	Extremely Uncomfortable	Comfortable
Travel time	Uncomfortable	Comfortable
Air condition	Extremely Uncomfortable	Comfortable
Air quality	Comfortable	Comfortable
Lighting	Uncomfortable	Comfortable
Visual Comfort	Uncomfortable	Comfortable

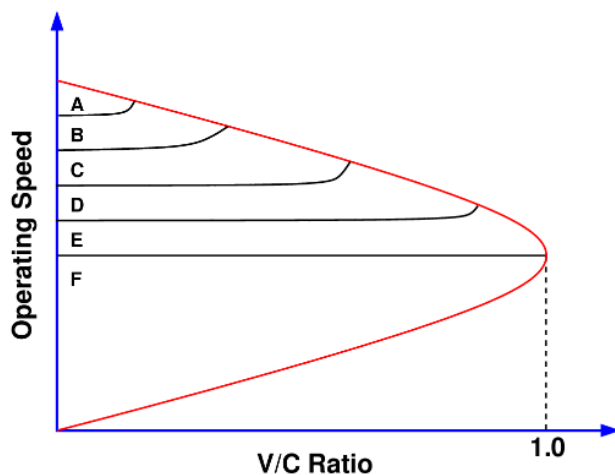


Figure 5. The operating speed and volume to capacity (v/c) ratio are used to express the level of service of the mid-block section [3].

The following numbers can be used as the facility's capacity because such a facility is regarded as ideal.

- A lane's capacity is 2000 vehicles per hour at 115 kmph.
- A speed of 80 kmph and a capability of 1900 automobiles per hour per lane.
- 2800 vehicles per hour, in both directions, at 100 kmph.

The *above-mentioned* values were statistically determined from the measured field values from numerous similar sections, not analytically or experimentally. It is crucial to note that a stream larger than this volume amount is conceivable but not essential. The aforementioned capacity values *decrease* as a result of numerous "non-ideal conditions," such as adjustments to travel time or speed, traffic restrictions or disruptions, etc. As a result, HCM has established multiple service levels for the traffic facility. *Several* user questionnaires that capture drivers' perceptions of the feature of the transportation under various working conditions are used to assign a quality value. The various operating situations and the Level-of-Services (A to F) are shown in Figure 4 along with the service quality (Table 4). After calculating the level of service for personal rapid transit system is LOS A [3]

Table 4. Mid-block section Level of service [3]

Level of Service	Quality	Speed (kmph)	V/C	Description
A	Free flow	80	0.6	Physical and psychological convenience on a high level
B	Reasonable Free- flow	70	0.7	An acceptable level of physical and psychological convenience
C	Near Free flow	60	0.8	Local deterioration possible with blockages
D	Medium flow	50	0.85	Non-recoverable local disruptions
E	At capacity flow	40	0.9	Minor disturbances resulting breakdown
F	Congested flow	15	1	Breakdown of flow capacity drops

Time Consumption

The proposed system's cost and performance were also compared to the current shuttle bus services to the parking lots. NMC provided precise bus schedules for the employee parking lots as well as an overall cost estimate, but commercial confidentiality prevented further cost information from being provided. The service at the bus stop is on-demand, with limos whisking customers to their terminal as they arrive; however, when they return, they must request a pickup. From 06.00 in the morning to 23.00 at night, the airport metro station is operated in 20-minute intervals, with optimal times between 05.00 and 06.00 and on consumption (with an inherent response delay at other times. The total cost of NMC Nagpur's staff services was approximated and applied to the estimated driver split shifts for each service category (Table 5).

Table 5. Time comparisons between Bus and PRT system

Metro station	Passenger /day	Shuttle Bus time in minute			PRT System time in minute			Difference		
		Walk	Wait	Vehicle	Walk	Wait	Vehicle	Walk	Wait	Vehicles
Bus stop	3590	1	15-20	8	0.6	0.2	2.5	0.4	19.8	5.5
Staff	532	1	15-20	8	0.6	0.2	2.5	0.4	19.8	5.5

Capacity

The minimum headway among both trains is calculated in railroad practice by the situation that if one train stops rapidly, the train behind it may also stop before a crash happens. A "concrete block stop" is an example of this. The minimum headway is frequently estimated to be at least two of these stopping distances in order to provide a margin of safety. The flow into and out of stations defines the headway since trains halt in line, each blocking the train in front, and the trains are long [3] (Table 6)

Table 6. PRT capacity performance comparison [3]

Mode	Heavy Rail	Light Rail	Busway	PRT	Average Difference
Headway (Second)	110-200	70-360	20-300	0.6-3	283
Vehicle Capacity	350-3000	250-360	30-70	3-6	257
Theoretical Line Capacity	6-90	2-30	0.5-16	3.6-28	17
Peak Load Factor	0.4-0.8	0.5-0.7	0.3-0.6	0.2-0.5	0.2
Observed	6-50	1-10	1-11	1-9	14

Revenue

Transportation revenue is the name given to the funds set aside for transportation. Taxes and fees that the government collects from transportation-related and unrelated activities and allots to finance transportation programmers are referred to as transportation revenue. The data is collected from Nagpur Municipal Corporation transport department. The parameters of data collected are numbers of passengers, total kilometers, total trips, revenue, earning per kilometers (EPKM). The difference is calculated between bus service and PRT system (Table 7)

Table 7. Revenue collection of Shuttle Bus service and PRT system

Date	Total Passengers	Total Trips	Total KMs	Shuttle Bus Service		PRT System		Difference
				Revenue	EPKM	Revenue	EPKM	
10/11/2021	91	44	88	1123	12.76	910	10.34	2.42
10/12/2021	131	38	76	1593	20.96	1310	17.24	3.72
10/13/2021	125	40	80	1613	20.16	1250	15.63	4.54
10/14/2021	143	40	80	1783	22.29	1430	17.88	4.41
10/15/2021	58	38	76	692	9.11	580	7.63	1.47
10/16/2021	145	40	80	1830	22.88	1450	18.13	4.75
10/17/2021	98	42	84	1202	14.31	980	11.67	2.64
11/06/2021	54	38	76	477	6.28	540	7.11	0.83
11/07/2021	99	38	76	1008	13.26	990	13.03	0.24
11/08/2021	106	40	80	1061	13.26	1060	13.25	0.01
11/22/2021	142	44	88	1453	16.51	1420	16.14	0.38
11/23/2021	75	38	76	747	9.83	750	9.87	0.04
11/24/2021	91	40	80	901	11.26	910	11.38	0.11
11/25/2021	100	40	80	1021	12.76	1000	12.50	0.26
11/26/2021	69	38	76	692	9.11	690	9.08	0.03
11/27/2021	89	40	80	877	10.96	890	11.13	0.16
11/28/2021	92	42	84	909	10.82	920	10.95	0.13
12/13/2021	49	31	62	463	14.94	490	7.90	7.03
12/14/2021	69	31	62	698	22.52	690	11.13	11.39
12/15/2021	60	31	62	580	18.71	600	9.68	9.03
12/16/2021	30	31	62	300	9.68	300	4.84	4.84
12/17/2021	68	31	62	674	21.74	680	10.97	10.77
12/18/2021	57	31	62	503	16.23	570	9.19	7.03
12/19/2021	99	31	62	984	31.74	990	15.97	15.77
Grand Total	2140	897	1794	23184	12.923077	21400	11.92865	0.9944259

RESULT & DISCUSSION

Feasibility

Operational Feasibility

The Figure 6 indicates that PRT system is more feasible than existing bus service. The headway of existing service is 5 minutes whereas the headway of PRT system is 0.03 minutes. The speed of existing bus service more than PRT system but bus departs according to their time and number of passengers. Therefore, PRT system is more feasible than bus system and should increase more use of public transportation [6–7].

Safety

Safety is one of the most important parameters in public transportation. According to data analysis the PRT system does not have any accident records till date whereas existing service having number of accidents in Nagpur from 2015 to 2021. Where in 2015 5 accidents occurs in that 1-person death and 8 persons injured. In 2016 6 accidents occurs in that 2-person death and 7 persons injured. In 2017 4 accidents occurs in that 1-person death and 5 persons injured [8]. In 2018 5 accidents occurs in that 1-person death and 6 persons injured. In 2019 6 accidents occurs in that 3-person death and 9 persons injured. In 2020 1 accident occurs in that 0-person death and 2 persons injured due to covid-19 number of accident decrease. In 2021 4 accidents occurs in that 2-person death and 6 persons injured. So, after analysis PRT system is safest transport system (Figure 7).

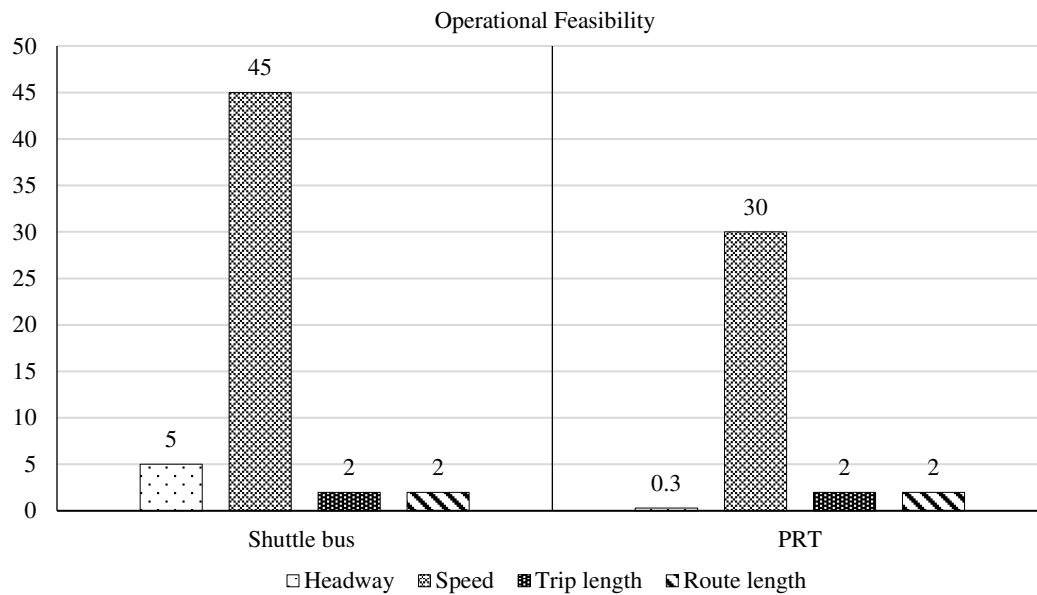


Figure 6. Comparative analysis between existing Bus service and PRT system.

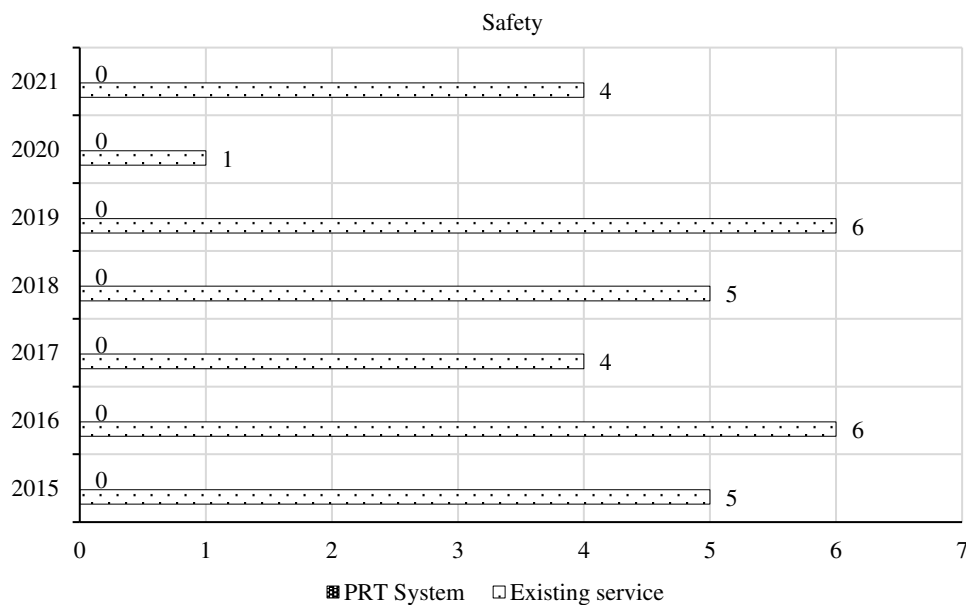


Figure 7. Comparative analysis of safety between existing service and PRT system.

Comfortness

The PRT system is more comfortable according to passenger’s survey and according to their rating. The parameters like maintenance, air condition, air quality and travel time passengers was not satisfied with existing services. According to analysis PRT system is more comfortable and feasible mode of transport (Figure 8).

Time Consumption

Time consumption is important parameter in transportation. The passengers coming from metro to walk 1 minute to bus stop the waiting for bus service till minimum 20 minutes and travel time is 8 minutes whereas PRT system is more feasible because passengers need to walk 30 seconds waiting time is 20 seconds and travel time is 2.5 minutes. The difference between bus system and PRT system is walking time is 30 seconds waiting time is 19.40 minutes and travel time is 5.3 minutes. Therefore, PRT system is more feasible (Figure 9).

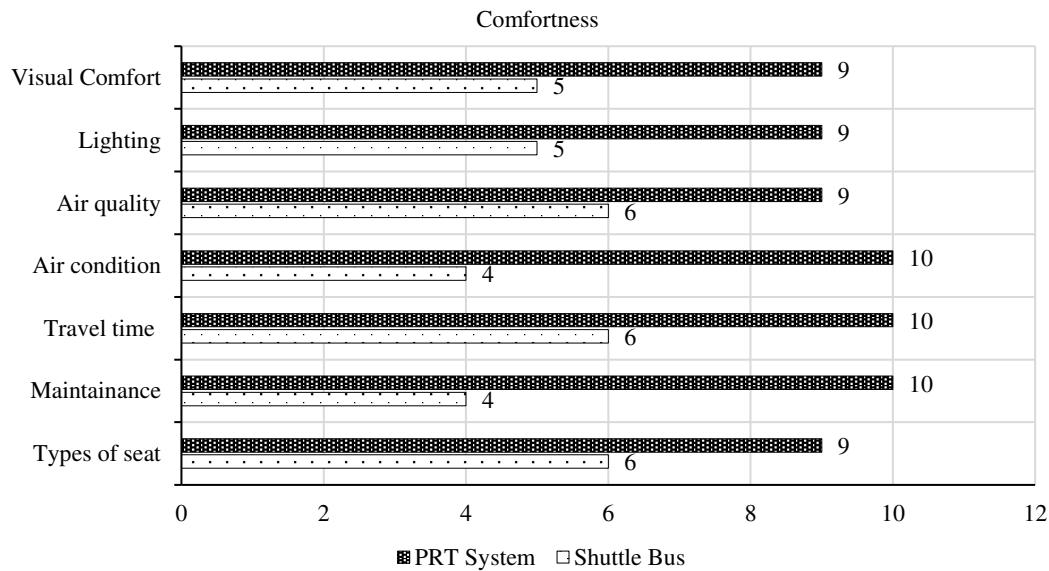


Figure 8. Comparative analysis of comfortness between bus service and PRT system.

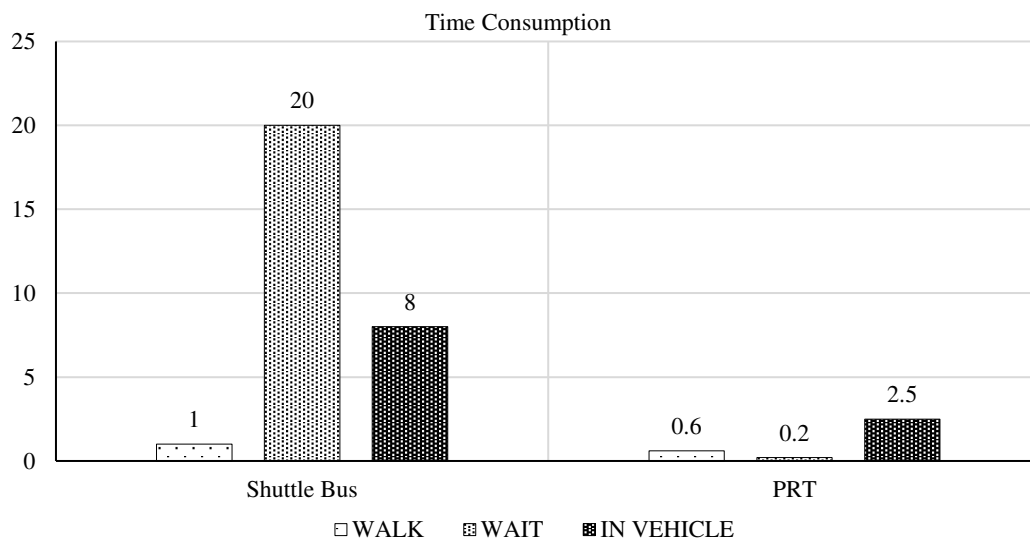


Figure 9. Comparative analysis of time consumption between bus service and PRT system.

Revenue

Providing the appropriate service to the appropriate customer at the appropriate time and at the appropriate cost (price discrimination, market segmentation). Many economic sectors use it. Potential for cost savings and revenue growth. Automated fare collection technologies make this possible. The earning per kilometers (EPKM) of bus system is more than PRT system because due to having no other option in Nagpur airside application service. The difference in between both services EPKM is 3.83 INR is average amount of collected data (Figure 10).

Comparative Summary

Walking time: The inexpensive budget of Personal Rapid Transit system stops, particularly unknown they are at earth level, allows for the introduction of additional stops without suffering significant costs overall. As a result, walking distances can be shortened considerably.

Waiting time: Studies for Heathrow ULTra use, utilizing a modelling device built in depth, reveal that with the 78 pods utilized in the cost profit estimations, average wait time are decreased to below

20 seconds. Trip time: PRT does not need to stop at two stations, it has a lower top speed but excellent trip times. Flexibility: PRT systems' compact size offers significant installation advantages. If necessary, the PRT system's radius of curvature can be as little as 5m. PRT has significant advantages over APM/LRT systems but cannot be as flexible as a bus. Disruption: Although some little groundwork is unavoidable, the infrastructure may be erected in its entirety in a few of months. For Heathrow, installation is anticipated to take place exclusively at night. Innovation: PRT's novel problems are frequently seen as a key deterrent when using PRT for airport applications, and they merit specific attention (Table 8).

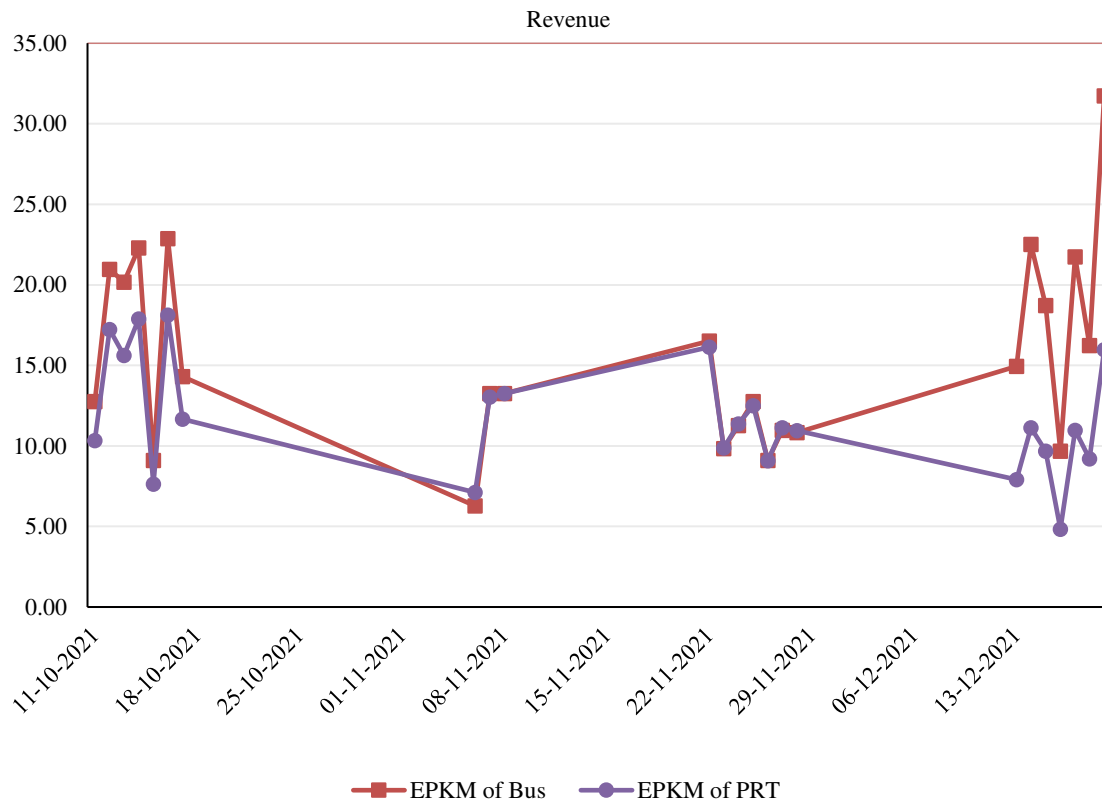


Figure 10. Comparative analysis of Revenue between bus service and PRT system.

Table 8. Comparative summary of modes of transportation

	Automated People Mover	Light Rail Transit	BUS	Personal Rapid Transit system
Walking	Moderate	Moderate	Moderate	Good
Waiting	Bad	Bad	Bad	Good
Trips	Good	Good	Bad	Good
Flexibility	Bad	Bad	Good	Moderate
Disruption	Bad	Bad	Good	Good
Cost	Bad	Bad	Good	Moderate
Invention	Moderate	Moderate	Good	Moderate

Thermoplastic and Thermosets

There are countless types of thermoplastics and thermosets, each with different material properties like plastic strain rate and service temperature; however, these variations are typical rather than universal. Designers must consider the benefits and drawbacks of each class of polymer, as well as categories, applications, and examples of frequently used materials, in addition to knowing whether a polymer is thermoplastic or thermoset (Table 9).

Table 9: Comparison between Thermosets and thermoplastic

Type of Resistance	Thermosets	Thermoplastic
Heat	More	Less
Chemical	More	Less
Deformation	More	Less
Impact	Less	More
Shattering	Less	More

CONCLUSION

When connecting the staff and passenger parking lots to the Airport terminal areas, Personal Rapid Transit system can provide several advantages. PRT provides:

- The speed, convenience, and privacy of a private vehicle; The capacity of public transit; Fewer or no waits and more frequent stoppages; A classification that is peaceful and non-polluting.
- A small-scale, unobtrusive guideway that can accommodate sharp turns, narrow radii, and steep grades; A system that is modular and adaptable for quick, low-cost construction that causes little disturbance and can be moved about reasonably simply; Infrastructure that is successfully incorporated into the airport in an engaging and enjoyable manner, with stations located inside passenger terminals.

Personal Rapid Transit is thought to be in a good fit for airports' demands for landside transportation:

- It provides a 40% operational cost savings over the current transport bus services.
- The predicted average passenger time savings at Heathrow is 8.5 minutes, or 60% of the existing transfer times.
- The system is expected to have affordable capital costs, especially when compared to Light Rail/APM, and it offers a 22 percent first-year rate of return, primarily in the form of passenger advantages. There are risks with any new system, however, and these costs are expected to be moderate. These are allegedly controllable for ULTra.

Thermoplastic sandwich body panel

- For a mass transit vehicle, a thermoplastic sandwich body panel's design, analysis, and production were completed.
- The face sheet was made of PP honeycomb, and the core was made of glass/PP woven tape. The design and analysis were done using the Pro/E, Hypermesh, and codes.
- It was successful to produce a body panel pan component segment with a PP honeycomb core, an inner face sheet made of two layers of woven tape glass/PP, and an outer face sheet made of four layers of woven tape glass/PP.
- The pan portion of the body panel underwent flexural testing, and the APTA static design requirement was effectively met. The measured deflection is just slightly less than what the finite element analysis predicted.
- The localized deboning and the relative motion at the adhesively bonded contact are blamed for the discrepancy in deflection between the finite element prediction and the experiment
- Long-term, the system might provide comparable advantages for airside operations.

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