Australasian Transport Research Forum 2016 Proceedings
16 – 18 November 2016, Melbourne, Australia
Publication website: http://www.atrf.info

Design and Feasibility Analysis of Personal Rapid Transit Network for an Indian Heritage City

Jayvant Choudhary[1], Anshuman Sharma[2]

[1]Indian Institute of Technology (Banaras Hindu University), Varanasi, India

[2]Indian Institute of Technology, Roorkee, India

Email for correspondence: Jayvant05@gmail.com

Abstract

Personal Rapid Transit (PRT) is a state-of-art amalgamation of automotive, computer, network and transit technologies which could prove to be very economical if properly managed. In this study, a PRT network is proposed for the city of Varanasi in India which is one of the oldest cities in the world. The study area constitutes of narrow streets having mix traffic with a predominance of pedestrians and slow moving vehicles. The proposed track connects the primary tourist and heritage spots of Varanasi to various centers of crowd generation. Proposed PRT network will provide the last mile connectivity to targeted spots which are otherwise tough to provide with conventional means of transit due to their higher need for space, infrastructure and due to a large amount of generated air and noise pollution. Various primary and secondary data were collected from different sources for efficient planning of PRT system. Travel demand assessment for PRT network was done after calculating the base year trips for the study area. Apart from capacity analysis, the financial viability of proposed project was analyzed based on financial analysis of 30 years and by calculating Internal Rate of Return (IRR).

The capacity of proposed PRT network was found to accommodate successfully the net demand arise during the peak and non-peak hours. This will ensure the reduced congestion on the roads and subsequently faster movement of traffic. After the systematic analysis of various parameters and by charging a reasonable fare based on the opinion of targeted population, an optimum IRR of 17% can be gained which is excellent for any business model. This study concludes that PRT could bridge the gap between traditional modes of transit that we have inherited and transit focused urban forms to ensure fulfillment of sustainability goals.

Keywords: PRT; sustainability; financial analysis; feasibility analysis; transit system

1. Introduction

In order to, development of vibrant and thriving living conditions in a city a good plan urban transportation system needs to be developed. However, the conventional mode of public transports is susceptible to challenges such as limited land; high capital and operating costs; increasing congestion; lower travel speed; the elevated rate of road accidents; alarming increase in pollution and susceptibility to crimes and vandalism. There is a need to bring forward more promising new technologies to counter aforesaid challenges.

Personal Rapid Transit or PRT is on demand, advance, non-stop, environmentally viable origin to destination service, which consist of small and automatic vehicles running over small and exclusive use guideways (Carnegie & Hoffman 2007). It is a state of art amalgamation of automotive, computer, network and transit technologies which could prove to be very economical if properly managed. PRT system comprises the attributes of a personal car and has a very low environmental impact. This system constitute of small, light weight, fully automatic, individually controlled and electrically driven vehicles (known as “pods”) which run along the dedicated guideways situated on, above or beneath street levels. PRT network consists of interconnected loops and offline stations, making non-stop travel possible between any two stations and provide last mile connectivity to users. PRT guideways are light weighted and don’t acquire much space for construction. Stations can be customized to fit in specific area and can also be integrated into new buildings.

PRT pods are computer-controlled and do not require any human drivers. A software program acquires the optimum path for each passenger and maintains a minimum distance between two vehicles in order to avoid collisions. PRT offer high safety standards for the passengers with the help of track and vehicle location systems that permanently monitor each vehicle. Pods are equipped with air-conditioning, comfortable seats, and an on-board information system with audio and video communication interfaces. Pods are designed to contain passengers with bicycles, wheelchairs or prams. The capital cost and energy consumption per capita rate of PRT network are also lesser than other conventional modes of public transport systems (Australia 2010). Due to electrically powered vehicles, the air pollution in the city is zero, and the level of noise is negligible. So it could serve as viable alternate to encounter challenges faced by conventional mode of transits.

2. Chronological advancement of PRT

PRTS seems to be a relatively new concept for India but in reality, it has been developing since early 1950’s. Don Fichter, a city planner, was credited with developing early concepts of PRT in 1953 (Fichter 1964). He addressed the requirement for a transportation system that could utilize the smallest and lowest-cost guideways possible and a service designed to fulfill the needs of travelers with the lightest possible vehicles. In 1972 the University of West Virginia in Morgantown started a limited operation of PRT system which was expanded to current capacity in 1975. This system was developed in order to move students between three campuses of distributed across the city with congested streets. It is considered as GRTS (Group Rapid Transit System) as it can transfer up to 21 passengers. It included 8.7 miles of guideway, five offline stations and fleet of 71 vehicles that could serve 30000 riders per day at peak travel times.

Blide (1993) stated that feasibility study of PRT system in Gothenburg, Sweden revealed it to be a most feasible option for the city. This system had a unique grid and “Spiderweb” configuration and can accommodate 6,00,000 trips per day with an average wait time of only 1.3 minutes. One of the most significant PRT programs is Chicago/Raytheon program in mid-1990’s which resulted in the construction of 2200 feet long test track in Marlborough, Massachusetts accommodating three vehicles and one off-line station with 2.5 seconds headway operation (Anderson 2006). The edict (Evaluation and Demonstration of Innovative City Transport) program was a European program sought to develop PRT as a potential urban transport solution to meet the need for sustainable new transport systems. It was a 30-month project that was started in December 2001 and ran through May 2004. The main objectives of this program are to study the opportunities for PRT implementation in Cardiff, (Wales), Huddinge (Sweden), Eindhoven (Netherlands) and Ciampino (Italy) and access the potential benefit of PRT in Europe (EDICT 2003).

In 2002, 2getthere unveils twenty-five, 4-passenger “Cyber-Cabs” at Holland’s 2002 Floriade horticultural exhibition. The system’s track was 1969 feet long and is one way constituting of two stations. The six months operation of the system was to observe the public acceptance towards the system. In October 2005, BAA (British Airport Authority) and ATS (Automated Transport Systems) announced an agreement to adopt a pilot implementation of the ULTra PRT system for Heathrow Airport, London. In 2007, the Polish PRT system named as MISTER was prototyped and was permitted to be installed in two Polish cities. MISTER is a typical overhead PRT system engineered for economical aerial reuse of street's right of way. In June 2006, a Korean/Swedish consortium, Vectus started constructing a 1,312 feet test track in Uppsala, Sweden. This system was demonstrated at the 2007 Pod Car City conference in Uppsala, Sweden (Carnegie & Hoffman 2007). A 40-vehicle, 2 station, 4.46 km double tracked system is known as "SkyCube" was opened in Suncheon, South Korea in April 2014 in order to reduce the pollution due to the impact of visitors transportation in nature reserves and bird sanctuary.

As of July 2013, four PRT systems are operational: Morgantown PRTS, which has been in continuous operation since 1975. A 10-vehicle 2getthere system is being operated since 2010 at Masdar City, UAE. A 21-vehicle Ultra PRTS is being operated at London Heathrow Airport since 2011 and a 40-vehicle Vectus system has officially opened in Suncheon, South Korea in April 2014 after a year of testing. India has yet to launch his first PRT system. However government in the year 2016 has laid the foundation stone for project Metro which would be first ever PRT system in India (Dash 2016).

3. Case Study- Varanasi, India

In the recent years tourism has grown in India from local economic activity to a major global industry giving employment to a large number of people at various levels. Varanasi is one of the districts of India with a great potential for tourism. Varanasi is situated on the banks of the holy Ganges in the Indian state of Uttar Pradesh, 320 kilometers south-east of the state capital Lucknow. It is located at 25°16′55″ North Latitude and 82°57′23″ East Longitude. Mixed traffic composition and narrow carriageways in old city area contribute to slow moving traffic. Varanasi is one of the oldest living cities on earth and home to the holiest shrines of religions such as Hindus, Muslims, Jains, and Buddhists. It includes locations such as the Kashi Vishwanath temple, Gyanwapi mosque, Sankat Mochan temple and Sarnath, etc. Thus, Varanasi is rich in historical, religious, and heritage sites.

Even though there is great potential for tourism in Varanasi, the city lacks planning for tourism and supporting infrastructure. Core area becomes chaotic during festivals and religious events as the number of pilgrims visits increase exponentially. The problem is become much more pronounced due to continual annual increase in registered vehicles. The traffic constitutes of mixed traffic with a predominance of two wheelers, auto-rickshaw and slow moving cycle-rickshaw, bicycles, and pedestrians. Frequent bottlenecks, poor traffic management and repetitive encroachments on the road by vendors increase troubles for the users in epic proportions. Frequent braking of vehicles not only increases the air and noise pollution but also cause frequent accidents. Measures were taken by local authorities like vehicle restricted zone etc. will help to address congestion problem in a limited manner, but it is not sufficient.

Basic objective of this study is to provide a sustainable transport infrastructure solution by integrating PRT System from railway station & BHU with Godowlia. Since there is a lack of proper public transport in the city, it is expected that PRT would reduce congestion on roads by accommodating a large proportion of traffic. The PRT network proposed in this study is two-way PRT network designed to connect 3 primary landmarks, i.e., Varanasi railway station, Banaras Hindu University and Kashi Vishwanath temple (Figure 1). At this route apart from other primary tourist spots, well established authorized commercial areas which attract shopping and recreational locations are also present. There is the presence of large university campuses like Banaras Hindu University and Kashi Vidyapeeth University in the study area which attracts education and works trips every day. Trips consist of access dispersal trips to the bus stops, railway station, shopping trips, recreational trips and educational trips within the study area.

4. Travel demand assessment

Primary and secondary data are needed for planning of PRT network and estimating demand travel assessment and modal shift. The primary data was collected through various surveys performed at different locations which are further assigned as PRT stations. The locations are selected on the basis of their capacity for trip generation and attraction. The locations are stated in Figure 1.

The trip, household, and socio-economic data were collected from the road side interviews and the similar data were collected from the workplace interviews in the establishment survey. Willingness to shift (WTS) and willingness to pay (WTP) surveys were conducted along side with both roadside interviews and workplace interviews. In these surveys, information about trip length, travel time, travel frequency and existing mode of transit were collected from users. After that, they were informed about PRT system, its utilities, and benefits. Then the users were asked about their willingness to shift to PRT if it will be introduced to their area. In the case of their positive response, they were asked at what fare they will be willing to shift to PRT. Secondary data was collected from municipal agencies and from previous studies.

4.1. Base year trips

The base year trips per day were taken as a number of persons traveling over the proposed route each day. The numbers of base trips for each mode were taken as the product of a number of the vehicle of a particular mode and its average occupancy. Average occupancy was calculated by dividing a total number of the person traveling using particular mode with total number of vehicles of that mode during peak hour. There was a need to calculate average occupancy because there was variation in a number of occupants from vehicle to vehicle. In the case of pedestrians, the average occupancy was taken as 1.0 only. The peak hour demand was taken to be 9.5% of daily traffic which was used as expansion factor for calculating base year trip per day.

Table 1: Calculation of base year trips

Trip Mode	Number of vehicles/ pedestrian at peak hour	Average Occupancy	Base Year Trip per peak hour	Base year trip per day
Two wheeler	3,168	1.3	4,119	43,558
Cycle-rickshaw	612	1.75	1,071	11,274
Auto-rickshaw	1,704	4.4	7,497	78,916
Car	996	2.8	2,789	29,358
Bicycle	1,218	1.1	1,218	14,106
Pedestrians	498	1.0	498	5,242
Total				1,82,254

4.2. Calculation of trip shifting to PRT

The primary data gathered from the willingness to shift and willingness to pay surveys was utilized to estimate the percentage of trips that will shift to PRT. What the ratio of a number of people willing to shift to PRT for each mode to a total number of people participated in the survey was calculated. This ratio was multiplied to daily base year trips to estimate travel demand for PRT.

Table 2: Peak-hour demand estimation for PRT

Trip Mode	Percentage shift	Base Year Trip per peak hour	Travel demand for PRT at peak hour	Travel demand for PRT per day
Two wheeler	63	4,119	2,595	27,316
Cycle-rickshaw	85	1,071	910	9,579
Auto-rickshaw	72	7,497	5,398	56,821
Car	77	2,789	2,148	22,611
Bicycle	40	1,340	536	5,642
Pedestrians	21	498	105	1,105
Total		17,314	11,692	1,23,074

4.3. Proposed PRT route

A two-way PRT route network of 8.0 km length with 9 stations was proposed in the case study area to meet the estimated travel demand. The network was designed to provide the highest level of accessibility by ensuring last mile connectivity to users. The stations were placed as per locations of primary CBD's, tourist spots and other locations for crowd generation. The station locations were also chosen based on the fact that, people should have access to another mode of public transportation if they need to travel further. The maximum acceptable walking distance was taken as 500 meters. The network connects major bus stops, railway stations, residential areas, institutional areas and commercial areas in the study area. The proposed route network has been shown in Figure 1.

4.4. Modal Split

As per calculated shift from each of the existing conventional modes, there will be a variation in the modal split of Intra Varanasi Trips when PRT is introduced. There will be a reduction in trips of each of the existing modes. The modal split in existing condition and the new expected modal split of Intra Varanasi trips have been stated below in Figure 2.

Results suggested that there will be a significant reduction of 31% and 15% of trips by auto rickshaw and two wheelers respectively. This will reduce congestion on roads and subsequently reduce the travel time. Reduction in congestion will reduce frequent braking of vehicles and reduce air and noise pollution. This will also help auto rickshaws to increase the number of trips on the same route at a given time.

Figure 1:Study area and proposed PRT network

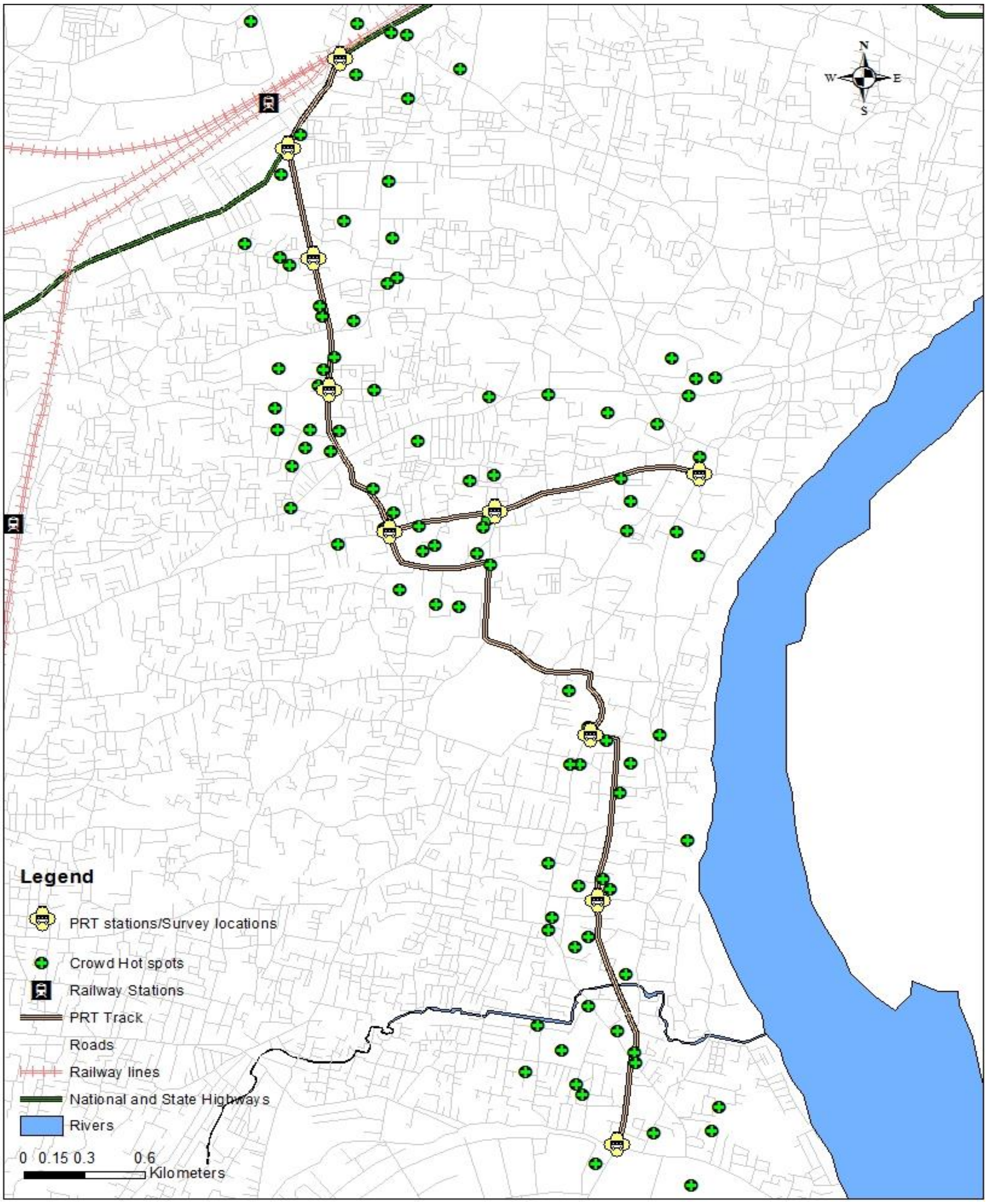
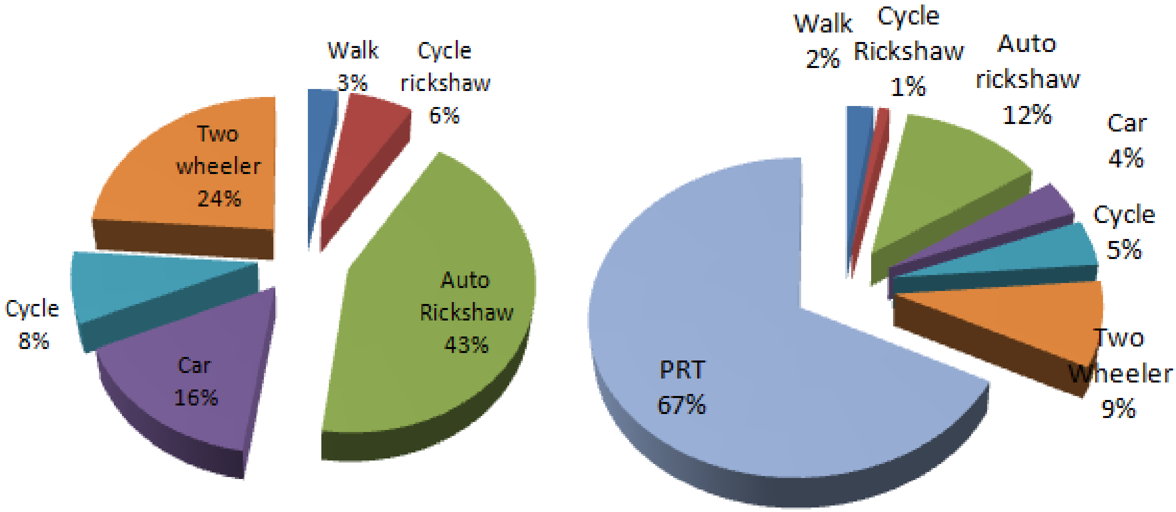


Figure 2: Modal Split before (left) and after (right) installation of PRT network



5. Supply capacity of PRT

The base year travel demand is 1,23,074 trips/day. The PRT supply capacity should be equal to or greater than peak hour demand. The PRT operational characteristics have been taken according to previous literature (Jain et al. 2014). The dwell time for PRT is assumed as 30 seconds. PRT can operate with minimum time headway of 3 seconds. The average time headway on which the proposed PRT system would run in peak hour is 3.6 seconds. The average occupancy of PRT has been assumed as 4, expecting that ride sharing will occur during the peak hour. An off-peak occupancy rate of 3 has been assumed, yielding an average occupancy rate of 3.3 (4.0 × 30% + 3 × 70%) (Mullar 2009)(Ultra Global PRT 2013).

The operational characteristics are taken as

1) Distance headway (Average) = 30 meters
2) Speed of PRT (Average) = 30 km
3) Average occupancy = 3.3 per pod
4) Average trip length = 3.3 km (from primary survey)
5) Route length = 8 km

The number of pod cars required to serve the peak hour demand has been calculated.

Time headway = distance headway ÷ speed

= 30 ÷ 8.33

= 3.6 sec

Time is taken to complete 1 trip = average trip length ÷ speed

= 3.3 ÷ 30

= 6.6 min /trip

Consider dwell time of 30 sec

Time taken to complete 1 trip = 6.6 + 0.5 = 7.1 min/trip

Number of trips made by each pod in 1 Hour = 60 ÷ 7.1 = 8.45 pod trips/hour

Number of Pods in 1 km length at any instant = 1000 ÷ Headway

= 1000 ÷ 30

= 33.33 pods/km

Number of pods in 1 km length for bi-directional track = 33.33 x 2

= 66.66 pods/km

Number of pods in the entire network length = no. of pods in 1 km track x route length

= 66.66 x 8

= 533 pods

534 pods are the maximum number of pods that the network can handle at the given speed & headway excluding the pods docked at stations.

Number of trips made by all pods in the entire network

= (no. of trips made by each pod) x (no. of pods)

= 8.45x 533

= 4507 pod trips/hour

Maximum number of passengers trips possible in the entire network

= (total pod trips) x (avg. occupancy)

= 4507 x 3.3

= 14,873 Passenger trips/hour

Considering 20 % Reduction for Empty Runs in the System

System Capacity = 14,873 - (0.2 x 14,873)

= 11,899 Passenger Trips/hour

Passenger – Km Covered in 1 Hour = System Capacity x Average Trip Length

= 11,899 x 3.3

= 39,265 Passenger-km per hour

The system capacity of the PRT system in Varanasi has been calculated to be 11,899 passenger trips per hour. The peak hour demand is 11,692 passenger trips per hour which are less than the system capacity. Hence, the system will be capable of handling the expected peak hour demand on the network. The difference between system capacity and peak hour demand is very little. This would not be the case during the rest of the day including the off-peak hours as the travel demand would not be same throughout the day. The number of Pod Cars required to achieve this system capacity is 533 Pod Cars excluding the pods docked at the stations.

5. Financial Analysis of PRT

Financial viability of a project is assessed on the basis of it's Net Present Value (NPV) and Internal Rate of Return (IRR). If the IRR value of a project is greater than 16%, then it is considered to be worth investing (Jain et al. 2014). Financial analysis of a project is based on numerous factors; in this study, these factors are classified into five categories. These are time factors; operational factors; demand factors; costs factors and financial factors. The 3 former categories are based on our surveys and analysis; however, the factors in latter 2 categories (cost and financial) are based previous literature (Jain et al. 2014) (Ultra Fairwood Green Transport 2009). It must be noted that financial analysis is based on rates of the year 2013.

Table 3: Factors affecting financial analysis

	Factors	Value
Time	**Concession Period**	30 years
	Construction Period	2 years
Operational	**Headway**	30 m
	Speed	30 km
	Average Occupancy	3.3
	Average Trip Length	3.3 km
	Route Length	8 km
Demand	**Base Year Trip per day**	1,82,253
	Percentage shift to PRT	67.53
	Desired Fare per km (Primary Survey)	Rs 4
	Estimated demand (trips/day)	1,23,074
	Ridership growth rate	5%
	Percentage increase in fare in every 3 years	20%
Costs	**Capital cost per km (In crores)**	44.48
	Operational and maintenance costs	
	a) Manpower cost (crore/year)	12.89
	b) Electricity cost	4.4
	c)AMC and Royalty	5% of fare
Financial	**Interest rate**	10%
	Loan repayment period	15 year
	Tax holiday	100% for 5 year
	Tax exemption	30% for 5 year
	Tax rate	35%
	Depreciation rate (pods)	20%
	Depreciation rate (civil structure)	5%
	Discount rate	10%
	CRF for given rate and loan replacement period	0.13147

These factors were used for preparing the Cash Flow statement of the project. The Cash Flow statement provides the net inflow and outflow of cash during concession and construction period. It depends on upon the Operating Income and Operation & Management Cost of the project. The total operating Income is composed of Fare Revenue, Advertisement Revenue, and Commercial Rent revenue. The net operation and maintenance cost is composed of Manpower Cost, Electricity Cost, and AMC & Royalty Cost.

Capital cost is one-time setup cost for plant or a project. Generally, this amount is acquired through from the market in the form of loan for certain repayment period and interest rate. In this study, a loan of Rs 355.84 crores is needed to acquire at 10% interest rate and 15 percent repayment period. By multiplying total to Capital Recovery Factor of 0.13147, annual installment of repayment came out to be Rs 46.78 crores. In the case of operating income, rates for Fare, Ads, and commercial rent has been proposed to be increased by 20% after every 3 year period, in order to take inflation in the analysis.

The Net Operating Income has been considered as the difference between total revenue and total cost. The interest paid, and depreciation has been subtracted from the net operating income to get Profit Before Taxes (PBT). PBT is a measure of project's profit that excludes depreciation, Taxes & interest paid. Here 100% tax exemption is provided for first 5 years, and then 30% exemption is provided for next 5 years. Taxes have been calculated as 35% of PBT and deducted from PBT to acquire Profit After Taxes (PAT). The depreciation and interest have been added to PAT to acquire Cash Flow After Taxes (CFAT). The CFAT has been reduced to their Present Value considering the Discount rate as 10%. The detailed Cash Flow Statement was prepared and stated the Table 4. Finally, the NPV and IRR of the project were calculated from the cash flow statement. IRR is used to evaluate the attractiveness of a project or investment. If the IRR of a new project exceeds a firm's required rate of return, that project is desirable. In our case, the desirable rate of return is 16%. The NPV of the PRT project came out to be Rs 551.40 Crores, and the IRR came out to be 17%. This showed that not only proposed PRT network would be capable of accommodating the peak hour traffic of Varanasi but also it is an attractive financial investment.

6. Conclusion

The promise of PRT has been in the public discussion for over 40 years. It has not reached maturation for a variety of reasons but remains an enduring idea that offers the unique and rare combination of potentially improving the quantity and quality of transit service while reducing costs, congestion, and environmental impact. This opportunity is available through the innovative application of advanced yet commercially available technology in a new form designed for public transportation. This study initially discussed the advantages of PRT as well as it's technological advancement in last decades. The problem statement for Varanasi is discussed and a PRT track of suitable length is proposed. Primary and secondary data were collected from various surveys and from responsible authorities. The capacity analysis for proposed network was done, and the system was found to efficiently handle peak hour demand. After that, a financial analysis was performed, and PRT system estimated to provide a good IRR of 17%. Hence, the PRT project in Varanasi if properly implemented and managed can provide a fast, systematic, efficient, intelligent, safe and economical transport mode to Varanasi. It can be used as a part of a tourism industry if used in an intelligent manner. As a public transport, it seems to be a financially viable option as we saw in financial analysis. %. Hence, it could be employed as a future mode of transport for Varanasi.

Table 4: Cash flow statement of PRT

Year	CC	Operating Income				Operation and Management Cost				NOI	IP	Dep	PBT	Taxes	PAT	CFAT	Present value of CFAT
		FR	AR	CR	TR	MC	EC	AMC & Royalty	TC								
2014	126.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-126.88	-115.35
2015	228.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-228.93	-189.20
2016	0.00	59.30	1.73	1.73	62.76	12.93	4.41	2.96	20.30	42.46	46.78	37.06	-41.38	0.00	-41.38	12.05	9.05
2017	0.00	62.26	1.82	1.82	65.90	13.06	4.63	3.11	20.80	45.10	46.78	31.2	-32.88	0.00	-32.88	14.69	10.03
2018	0.00	65.37	1.91	1.91	69.20	13.19	4.86	3.27	21.32	47.88	46.78	26.44	-25.34	0.00	-25.34	17.47	10.85
2019	0.00	82.37	2.41	2.41	87.19	13.32	5.11	4.12	22.55	64.64	46.78	22.56	-4.70	0.00	-4.70	34.24	19.33
2020	0.00	86.49	2.53	2.53	91.55	13.46	5.36	4.32	23.14	68.41	46.78	19.39	2.24	0.00	2.24	38.00	19.50
2021	0.00	90.82	2.65	2.65	96.12	13.59	5.63	4.54	23.76	72.37	46.78	16.78	8.81	2.16	6.65	39.80	18.57
2022	0.00	114.43	3.34	3.34	121.12	13.73	5.91	5.72	25.36	95.76	46.78	14.63	34.35	8.42	25.93	56.94	24.15
2023	0.00	120.15	3.51	3.51	127.17	13.86	6.21	6.01	26.08	101.10	46.78	12.85	41.47	10.16	31.31	60.53	23.34
2024	0.00	126.16	3.69	3.69	133.53	14.00	6.52	6.31	26.82	106.71	46.78	11.37	48.56	11.90	36.66	64.40	22.57
2025	0.00	158.96	4.65	4.65	168.25	14.14	6.84	7.95	28.93	139.32	46.78	10.13	82.41	20.19	62.22	88.72	28.27
2026	0.00	166.90	4.88	4.88	176.66	14.28	7.18	8.35	29.81	146.85	46.78	9.09	90.98	31.84	59.14	84.60	24.51
2027	0.00	175.25	5.12	5.12	185.49	14.43	7.54	8.76	30.73	154.76	46.78	8.2	99.78	34.92	64.86	89.43	23.55
2028	0.00	220.81	6.45	6.45	233.72	14.57	7.92	11.04	33.53	200.19	46.78	7.45	145.96	51.09	94.88	118.70	28.42
2029	0.00	231.86	6.78	6.78	245.41	14.72	8.32	11.59	34.62	210.78	46.78	6.81	157.20	55.02	102.18	125.36	27.28
2030	0.00	243.45	7.11	7.11	257.68	14.86	8.73	12.17	35.77	221.91	46.78	6.25	168.88	59.11	109.77	132.40	26.19
2031	0.00	306.75	8.96	8.96	324.67	15.01	9.17	15.34	39.52	285.16	0.00	5.75	279.41	97.79	181.62	187.37	33.70
2032	0.00	322.08	9.41	9.41	340.91	15.16	9.63	16.10	40.89	300.02	0.00	5.32	294.70	103.14	191.55	196.87	32.19
2033	0.00	338.19	9.88	9.88	357.95	15.31	10.11	16.91	42.33	315.62	0.00	4.95	310.67	108.74	201.94	206.89	30.75
2034	0.00	426.12	12.45	12.45	451.02	15.47	10.61	21.31	47.39	403.64	0.00	4.61	399.03	139.66	259.37	263.98	35.67
2035	0.00	447.42	13.08	13.08	473.57	15.62	11.14	22.37	49.14	424.44	0.00	4.31	420.13	147.04	273.08	277.39	34.08
2036	0.00	469.79	13.73	13.73	497.25	15.78	11.70	23.49	50.97	446.28	0.00	4.04	442.24	154.79	287.46	291.50	32.55
2037	0.00	591.94	17.30	17.30	626.54	15.93	12.29	29.60	57.82	568.72	0.00	3.79	564.93	197.73	367.20	370.99	37.67

2038	0.00	621.53	18.16	18.16	657.86	16.09	12.90	31.08	60.07	597.79	0.00	3.56	594.23	207.98	386.25	389.81	35.98
2039	0.00	652.61	19.07	19.07	690.76	16.26	13.55	32.63	62.43	628.33	0.00	3.35	624.98	218.74	406.23	409.58	34.37
2040	0.00	822.29	24.03	24.03	870.35	16.42	14.22	41.11	71.75	798.60	0.00	3.16	795.44	278.40	517.04	520.20	39.68
2041	0.00	863.40	25.23	25.23	913.87	16.58	14.93	43.17	74.69	839.19	0.00	2.98	836.21	292.67	543.53	546.51	37.90
2042	0.00	906.58	26.50	26.50	959.57	16.75	15.68	45.33	77.76	881.81	0.00	2.82	878.99	307.65	571.34	574.16	36.19
2043	0.00	1142.3	33.38	33.38	1209.05	16.92	16.46	57.11	90.49	1118.6	0.00	2.67	1115.89	390.56	725.33	728.00	41.72
2044	0.00	1199.4	35.05	35.05	1269.51	17.08	17.29	59.97	94.34	1175.2	0.00	2.52	1172.64	410.43	762.22	764.74	39.84
2045	0.00	1259.4	36.81	36.81	1332.98	17.26	18.15	62.97	98.38	1234.6	0.00	2.39	1232.22	431.28	800.94	803.33	38.05

Net Present Value= Rs 551.40 Crores   Internal Rate of Return = 17%

All Values in Crores (Indian Rupees), 1 Crore = 10 Million, 1 INR = 48 AUD (Current exchange rate)

Abbreviations:

CC=Capital Cost; **FR**= Fare Revenue; **AR** =Advertisement Revenue; **TR**= Total Revenue; **MC**=Man power cost; **EC**= Electricity cost;

AMC = Annual Maintenance Cost; **TC**=Total cost; **NOI**= Net Operating Income; **IP**=Interest Paid; **Dep**=Depreciation; **PBT**=Profit Before Tax;

PAT = Profit After Taxes; **CFAT** = Cash Flow After Tax

7. References

Anderson, J.E., 2006. The future of high-capacity personal rapid transit. *PRT International, LLC. Minneapolis, MN. Retrieved* January.

Australia, I., 2010. Our Cities-building a productive, sustainable and liveable future. *Department of Infrastructure and Transport, Canberra, ACT: Commonwealth of Australia*.

Blide, B., 1993, October. APM Activities in Gothenburg. In Automated People Mover IV, (pp.566-574). ASCE.

Carnegie, J.A. and Hoffman, P.S., 2007. *Viability of personal rapid transit in New Jersey* (No. NJ-2007-001)

Dash D.K. 2016. Global Bids for Gurgaon Pod Taxis in April. *The Times of India*, *New Delhi*.

EDICT Consortium, 2003. Midterm Assessment Report. *Transport & Travel Research*. *Retrived November.*

Fichter, D., 1964. *Individualized automatic transit and the city.*

Jain, U., Sarkar P.K. and Vibhuti, A., 2014. Benchmarking of Personal Rapid Transit System (Dynamic Model). In *Transportation Research Board 93rd Annual Meeting* (No. 14-0027)

Peter J. Muller. 2009. The Impact of PRT on Army Base Sustainability, *Fort Carson Army Post, Colorado Springs, PRT Feasibility*

Ultra Fairwood Green Transport. 2009. DPR of PRT Amritsar Project. *Detailed Project Report.*

Ultra Global PRT. 2013. Ultra Global Simulator – Tutorial. *http://www.ultraglobalprt.com/about-us/library/ultra-simulator*.