
EFFICIENCY IN PLANNING FOR SURFACE PUBLIC TRANSPORTATION

Monalisa Malani

*Student, Faculty of Architecture, Manipal Academy of Higher Education
Manipal, Karnataka, India*

Abstract: Rapid urbanization is making urban traffic congestion increasingly rigorous, and its contradiction among resource, population and environment is becoming increasingly prominent. The hierarchy of green transportation puts cyclists and pedestrians first because of its low cost, space efficiency, and zero environmental impact; followed by public transit because of its shared passenger-transport service, thereby helping in reduction of an individual's carbon footprint. The government has therefore, aimed at constant development of the public transport system in the country for better connectivity and to promote a healthier lifestyle. The expansion of this sector will lead to construction of new transportation hubs to support it. Research on efficient planning for these public transit hubs is relatively underdeveloped. Buses act as the highest acceptable mode of public transportation in India, this paper aims at Efficient planning techniques for the construction of infrastructure supporting public transportation and to promote non-motorized transit modes. The outcome of this study would be utilized by the researchers to have an idea as to how the aspect like planning of green design will cause a difference in the society not only economically and socially but also environmentally and also moving towards a green development path.

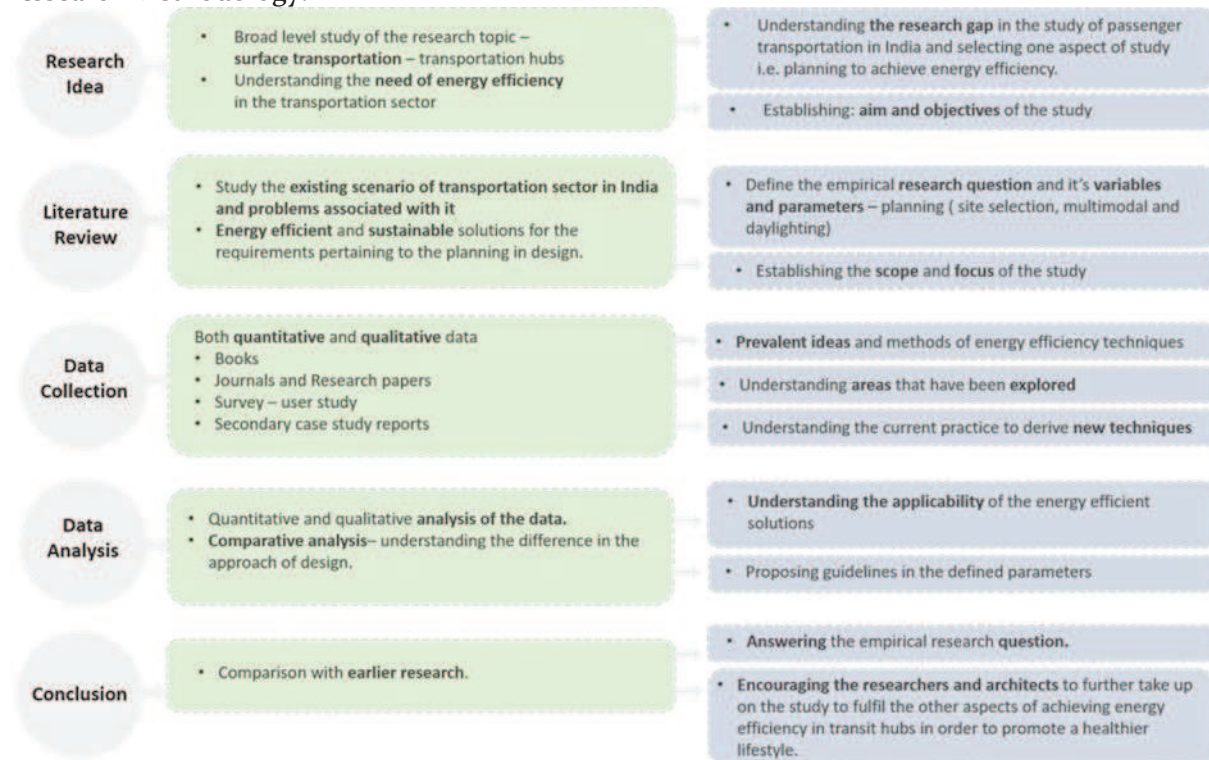
Keywords: India, Planning, Public Transportation, Transit Hubs.

Introduction: The transport sector in India has been growing rapidly, especially post-independence, both in terms of physical spread as well as capacity to meet the rising mobility demands for both passengers as well as freight. On the other hand, the transportation infrastructure in India has been failing to meet those reciprocating mobility demands in terms of coverage, capacity as well as service quality. This negligence in the balanced development of the transport sector has led to several negative externalities in terms of increasing congestion, increasing emissions resulting in depleting air quality, rising health related risks, increase in deaths due to road accidents, increasing dependency on fossil fuels and an overall depleting quality of life.

Aim: The aim is to establish sustainable and energy efficient control methods right at the planning stage of the construction of transit hubs, supporting the ever-growing mobility needs of the surface transportation. Also, encouraging investment in the public sector development to promote a modal shift from the currently observed privatization of transport sector to a more efficient public transport.

Objectives: The following are undertaken as objectives of the study:

1. Understanding the current scenario of transportation sector in India.
2. Establishing the importance of public transportation and its supporting infrastructure for road transportation.
3. Developing efficient methods in planning stage of design, through following parameters:
site selection; multimodal system; design elements and techniques
4. To develop guidelines that should be applied in design development stage

Research Methodology:

Scope: It defines the depth and breadth of the topic. As mentioned earlier, this paper will aim at understanding and developing guidelines to achieve energy efficiency at planning stage of the design.

- Study for current scenario
 - Road transportation sector in India and its importance
 - Need to shift to public transportation
 - Reason for decline in public transportation
 - Need for infrastructure development
- Efficient methods in planning with parameters, like
 - site selection – centralized/decentralize; mixed use development
 - intermodal planning
 - design elements and techniques
- For each design parameter:
 - Understanding how that parameter paves a way for “green” transport
 - How to achieve energy efficiency in those parameters – design guidelines

Focus: This study matter and the design guidelines will focus on the following:

- Public passenger transportation and Non-Motorized Transportation
- Indian context

Road Transport Sector in India – An Overview: Transportation acts as the wheels to the engines of growth of a town/city/nation. For a country’s socio-economic development, it is important to look into transportation and its supporting facilities. The transportation sector is broadly categorized into air, land (road, rail) and water modes. The road network of India is of 4,689,842 kilometers (second largest), comprising of national highways, expressways, state highways, major district roads, other district roads and village roads. In India, road transport is the most widely used for both passenger and freight mobility. Concentrating only on passenger surface (road) transportation, the following statistics and data has been gathered to understand the current scenario in India, while realizing the demand for a sustainable approach in the development of surface transit hubs. [1]

Transport and energy are closely related. [2] One way to control the energy usage is to switch to better alternatives for fuel consumption. It is important to understand that, the excess energy consumption is not only restricted in terms of fuel consumption in transportation sector but also in the built environment supporting it. Even though fuel waste and air pollution caused by transport sector needs our highest attention, there is more to it that architecture and the built environment can contribute to through planning, designing and maintenance. There have been certain improvements in the transportation sector yet there are still several unresolved issues due to outdated infrastructure and lack of investment. [3] [4] There is a need to develop these infrastructures in a sustainable and efficient manner to meet our long-term needs. Here is where architecture plays its role.

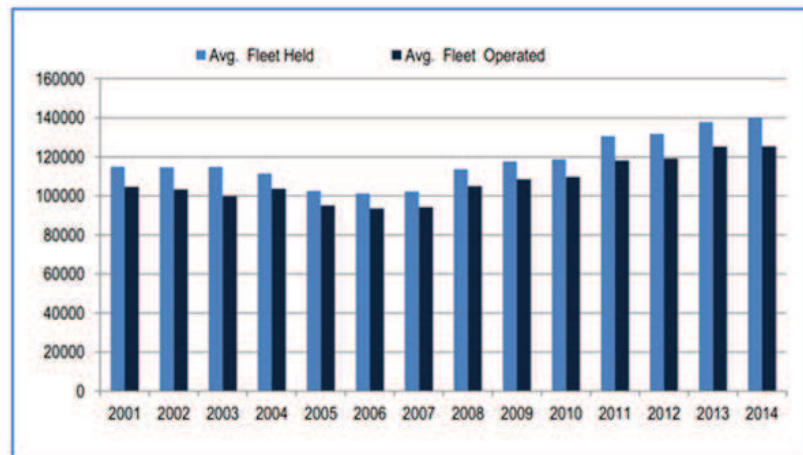


Figure 5: Growth in average bus fleet held and operated by STU's per year

Source: MoRTH (various years)

Need for Shift to Public Transportation: Vehicle composition: Number of registered motor vehicles have been constantly increasing in India. [5] Private ownership of vehicles has increased by 12% in the last decade and is expected to keep increasing due to rising standards of living, higher incomes etc. 86% of the total number of motor vehicles in the country are under private ownership, dominating the vehicle composition of the country. This rapid growth of registered motor vehicles will add up to the poor traffic situation in the country and worsen the related problems of increasing pollution levels, traffic congestion, and vehicular emissions, increased energy consumption which will in turn have a negative impact on the health and quality of life.

One of the most sustainable aspects of the transportation sector is a shift to Non-Motorized Transport (NMT) and Public Transport (PT), which helps in reducing the per capita carbon footprint, thereby moving towards a healthier development.

Reason for Decline in Public Transportation: Surface transportation services by Government's State Transportation Undertaking (STU) are responsible for providing transportation services for intercity and interstate movement. Apart from the services provided by the STUs there are privately owned public transportation service providers who have emerged to overcome the gap in terms of quantitative and qualitative services. These services include various modes like buses, minibuses, auto rickshaws, taxis etc. In India, the share of buses held by STU's in terms of total registered vehicles has decreased over the years. [6] Even though there is an increase in the number of vehicles owned and operated by STU's since the implementation of Jawaharlal Nehru National Urban Renewal Mission (JnNURM) in December 2005, there has been a gradual decline in the number of passengers travelling through these proposed public modes of transit. [7] India is progressing in the wrong direction with its increase in percentage of personal vehicles in the total motor vehicle composition. There is still a large section of the nation's population who cannot afford private vehicles. They are facing a huge disparity with respect to increased travel time and cost due to road congestion caused by increased number of vehicles. Hence, availability and ease of access to public transit modes is a major concern.

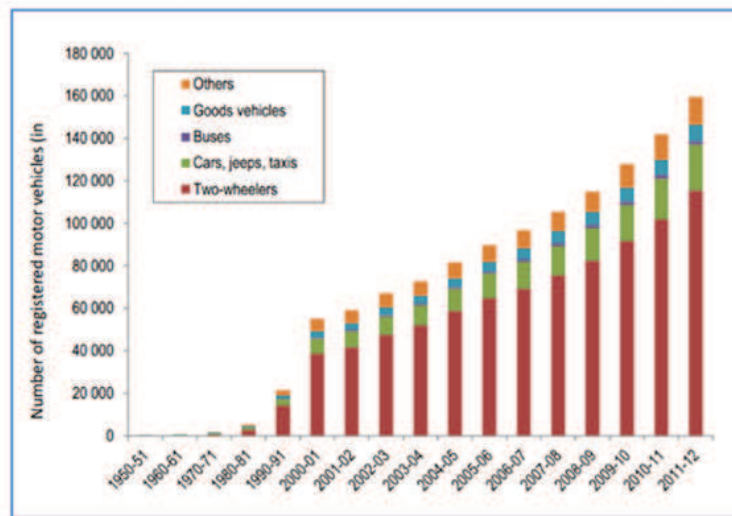


Figure 4: Growth in the total registered motor vehicles in India (1951-2012)

Source: MoRTH, 2013a

Need for infrastructure development: Infrastructure development supporting the road transportation network, is a critical enabler to economic growth. In the past decade, it has been realized that there is a need to develop nation's infrastructure catering to passenger movement yet there is only a little that has been done. The current infrastructure is not only insufficient, ill-equipped and ill-designed but is also at its higher rate of energy consumption. The increase in the road sector has surpassed the proportionate increase of its supporting infrastructure. This critical shortage of adequate transport infrastructure has led to issues leading to severe congestion, increased travel times, pollution etc. There is a need to pursue infrastructure development strategy that maximizes cost efficiency, users oriented quality services with low energy consumption.

These transport hubs act as the access points for the users. They are generally of large scale, as its occupant load or traveler load is determined by taking into consideration the entire region's current population and also the future increase. Hence, developing these transit hubs with sustainable and energy efficient techniques will help in addressing the current demands and ensure future stability.

1. Site Selection:

Passenger transit hubs play a vital role in the distribution pattern in transport networks. These hubs are flow concentrating structures as it is not exclusively used by just one user group. It acts as a public building catering to a broad network of people. The site selection for such buildings becomes really critical as these decisions once made will remain in effect for a long duration, especially due to the length of time for which the facilities will be available, its growing effect on the immediate context and the large amount of capital invested. Hence, choosing a site for the development of such infrastructure is not an easy task and therefore involves a lot of strategic thinking. With today's rapid growth and increasing concerns for human and environmental health, it is important to take a closer look at the building practices starting from the site selection. There are many aspects that can be examined with respect to how sustainable and efficient the chosen site is. For example, whether it is a new site or the existing, if it is located in an urban, suburban or a rural area etc. The location of public transport hubs is of great concern not only for the mentioned building but also for the sites and buildings present in its surrounding context. LEED system provides a great concern for proximity of transportation. It provides a total of 6 credits for those construction sites that are near to public transportation facilities. Due the presence of a public transit approach within 0.4-0.8kms walking distance will help in promoting the use of public transportation by the future occupants of the surrounding context. This will discourage them from opting for their own private vehicles. Resulting in reduce traffic, carbon emission, energy consumption and hence the negative impacts on the environment. Hence, the placement of transportation hubs becomes crucial.

General Guidelines:

- To maximize energy efficiency in terms of site selection of the transit hubs, one of the location efficient sites are often the previously developed areas. These areas are already provided with the supporting services such as streets, utility lines, water pipes, infrastructure and the already dependent neighborhood.
- It should also be well connected to the larger region of its establishment and close to amenities that will support the user flow for example - shops, restaurants, etc. Most of the times, these amenities develop after the development of the transit hubs in that area.
- The site selection should also keep in mind the land use pattern and zoning of the urban context it is supposed to reside in, so as to be reachable to a larger mass through non-motorized transportation modes i.e. walking, cycling. For example, if a transit hub developed at the remote corner of the city where the land use pattern caters to industrial development, it will only be helpful for a portion of industrial works (who are not residing in the nearby neighborhood) and the surrounding small development, if any. Whereas development of the transit hubs near larger concentration of population will bring in more flow of people and encourage higher usage.

i) Centralized or decentralized: The development of transit hubs should always be harmonized with the urban planning of the city. They are ideally located in the prime areas where it's easily accessible to larger group of people with high availability of different modes of transport and facilities. This is done with the aim to maximize the facilities at that area, while minimizing its effect on the environment and displacement of communities. Sometimes transportation hubs are located in the outskirts of city (decentralized) with the goal to promote outwards expansion. For example, in China, new transit hubs were constructed in areas that were not fully developed and were outside their urban center. With the construction of these hubs, the surrounding areas also started developing along and became the sub centers of the city. To ensure that the urban development is not fragmented, the new transit hubs should serve as a link between the new sub-center and the existing city center. Sometimes the complimenting development plans to the new transit hubs are not put into practice. Resulting in negative implications on the already constructed transport hubs. Urban planners, transport planners and transport operators should harmonize and balance the conflicts between urban planning and site selection of the new transit hub. This is because the development around the hub would take about 5-8 years, which should not make the hub's range of influence and connection to the city negligible. For example, in Bangalore, India due to its rapid increase in urban population, the HAL Bangalore Airport became incompetent in holding the increased user flow. Therefore, Bangalore had to scout for another location to construct a new airport terminal that can hold more people and traffic. Due to various geographical and land acquisition reasons, in 2008, Devanahalli (40kms north-east of Bangalore) was chosen as an ideal location for Bangalore's current airport i.e. Kempegowda International Airport, which now accommodates almost 15 million passengers per year. Resolving the capacity issue, the airport has become difficult to access due to the huge distance from the city and slow development of the town itself to provide the basic facilities. Was the site selection for the new terminal appropriate? Or could the old airport simultaneously continue operating alongside the new airport, while the development of the new terminal surrounding began? On the contrary, the inner core of the city of Ahmedabad, requires a dense network of transportation as it will house a very large density of population due to its mixed use integrated land use and transport infrastructure. Ahmedabad central railway station (Kalupur Railway Station) will be most critical intersection as it is situated right within the central core of the city (centralized). The project aims at replacing the central station with a multimodal transit and will integrate diverse modes of transportation including railways, metros and bus rapid transportation system. It is projected to have the highest number of originating passengers.

ii) Mixed Used Development: A model of urban planning that incorporates multitude of uses in a single urban development is referred to as mixed-use development. It includes residential, commercial – both office and retail, recreational and sometimes institutional, harmoniously blended together. The density and interconnectedness of a mixed-use neighborhood encourages the residents to opt for walking and NMT modes like bicycles. This is due to short trip lengths, as this type of development ends up placing the day-to-day things we need to do in immediate proximity to each other. This also

promotes the feasibility of public transportation in areas where it wasn't practical before, thus reducing the energy demands and environmental impact of an automobile-based commuter culture. For example, New York City, due to its healthy mix of residences, retails, offices etc. ends up vastly reducing the need for automobile usage and ownership. Residents routinely walk or use public transportation to reach their destination.

The spatial arrangement of the various land use and activities across a city should be well integrated in order to reduce the travel needs. This can lead to the development of compact cities for the better. Other benefits include a low-stress atmosphere, lower dependency on automobile, reduction in individual carbon footprint and many more. Due to this, the local users do not depend on automobile ownership, thereby reducing the need of parking lots, garages and impervious covers i.e. the road.

2. Government Laws

Apart from measures taken by our government to increase the investment in public transit modes there is only more that we can do to discourage the usage of privately-owned vehicles, i.e. by establishing government laws and regulations. In the last decade in Singapore, due to increase household income, the vehicle population had also simultaneously received a boost. Therefore, the Singapore government introduced an Additional Registration Fees (ADF) and a percentage of Open Market Value (OMV) as surcharge to discourage private vehicle ownership. General mechanisms that refrain the use of private vehicles could be through higher parking fees; reduced availability of parking spaces or higher fuel taxes for private vehicles. There are certain things that need to be addressed to, prior the formulation of these laws, such as:

1. Provision of differentially priced services. This is to accommodate people who can't afford higher prices with cheaper fares and premium services priced to accordingly benefit those who would shift from personal vehicles and require the extra quality and comfort that they have always aspired in their travel.
2. Pedestrians and non-motorized transit users have been squeezed out of the road for their safety. Segregation in the right of way for pedestrians and cyclists by providing bicycles lanes and sidewalks. Also, people travelling by private vehicles should have basic civic understanding and respect towards a pedestrian and NMT users, by allowing them to cross before them, ones contributing to a healthier environment.
3. There should be equitable allocation of road space, proposed by government. For example, a public bus carrying 30-40 passengers is allocated only 2.5 times the space given to a car, which usually will be carrying 2-3 people. The focus is on vehicle not on the number of people. Due to this people travelling through these high capacity transit modes (usually public transportation) end up paying in terms of higher travel time and cost because of the disproportionate space allocated to private vehicles. If only the allocation was for people, then more space would have been allocated to public transit. This can be achieved by reserving lanes for public transits, vehicles carrying more than 3 people (High Occupancy Lane) and pedestrians/non-motorized transit users. Strict penalties for violation of the same should be charged, in order to facilitate better enforcement of such lanes.

3. Multimodal/Intermodal Connectivity:

The energy demand of the transportation sector of a city can be reduced by promoting a shift from private transport modes to more sustainable modes i.e. public transportation and non-motorized modes, as mentioned earlier. [8]

However, the energy efficiency in transportation does not stop at promoting the public transportation and non-motorized transportation but it rather begins there. Intermodal transportation aims at providing two or more modes of transportation in a journey by combining the strengths of various transportation options and offsetting their weaknesses. It provides a set of choices of modes of transport; which travelers can use with different combinations according to their needs and preferences to reach their destinations. In the present conditions, the transport hubs are being built and developed in silos, which has resulted in extensive costs to the economy, society and environment. Due to lack of proper integration of these transportation modes, it has led to further worsening of the situation. There

is a need to adopt an integrated approach to develop a more balanced modal system, which is also recommended in the 12th Five Year Plan of India. This balanced system will lead to an efficient, reliable, safe, economical, sustainable and environment-friendly transportation hub.

The transit hubs are the primary interfaces for the passengers. It aims at a systematic movement of passengers to and from the high-capacity transit system to other modes of transportation. To ensure the long-term success of these hubs, it is important to obtain close connectivity among all the modes of transportation including pedestrian and bicycle connectivity. This can be achieved by focusing on seamless movement of passengers in accessing different modes. High level of efficiency is required in this intermodal connectivity, otherwise it may pose as a safety concern. Also, hindrance in the operation and services of the transit hubs are due to poor connections between the transit modes. The city planners and transportation agencies should consider these multi-use transit center as a way to reduce congestion, increase transportation efficiency, promote high density mixed used planning in the surrounding which will help in keeping the city compact.

How to Achieve It?

- a) Analyzing the possible modes of arrival to a transit hub
- b) Understanding the possible intermodal movement at the transit hub
- c) Identifying users, their issues and providing features for their transit access.

Users play a vital role in understanding the requirement and successful working of the intermodal hubs. Hence, a user-based survey was conducted to develop the guidelines required to establish an intermodal transit hub, considering the buses being the highest capacity transit mode.

a) *Analyzing the Possible Modes of Arrival to A Transit Hub:* Transit hubs cater to a variety of users. These users will access the transit hubs by a variety of means available at their disposal. Survey shows that auto rickshaw and walking are more preferred arrival modes by the users in a small town, Udupi. Others possible modes of arrival are - a private vehicle, a car, taxi, feeder bus, paratransit services etc. These various arrival modes need to be considered to provide suitable design features, thereby allowing them use these intermodal hubs at ease (refer the table above). From these various arrival modes, the users shift to a higher capacity mode, for e.g. bus but in between this switch, there is an intermediate change in the mode of travel i.e. walking. Therefore, the design should also ensure safe and seamless movement of pedestrians as they interact with other modes of travel at the transit hub.

Transit mode	Features
Railway	Railway tracks, passenger platform, waiting area with seating and other amenities
Metro	Metro tracks, passenger standing platform, waiting area
Bus	Bus bays, passenger platform, loading/unloading area, waiting area for passengers with seats and other amenities
Auto rickshaw and other Paratransit modes	Pick-up and drop-off points, auto stand, waiting area
Taxi	Pick-up and drop-off points, taxi stand, waiting area
Private vehicles	Pick-up and drop off points, parking area
Bicycle	Bicycle parking, pavement
Walking	Pavement, curbs, crossing points

Source: *Journal of the Transportation Research Forum*, Vol. 47, No. 3 (Public Transit Special Issue 2008)

b) *Understanding the Possible Intermodal Movement at the Transit Hub:* Typically, walking is the last mode of transportation before boarding the transit vehicle. All the passengers, arriving at the transit hub through various modes of transportation apart from walking, will switch to walking before changing to another mode of transit vehicle. For example, passengers arriving the transit hub by a private vehicle, will either get dropped off at the drop off point or will park the vehicle at the allocated parking area. Either way, from that point to switching to a higher capacity transit, for e.g. public bus, the user will have to walk from the parking /drop off area facility on the sidewalk on the way to platform. This

indicates that all the users in between the switch from one mode of transportation to another become pedestrians. Thereby, increasing the need of highly established walkways and pathways, interconnecting the various modes of travel offered by the transit hub to ensure safe, seamless and convenient interaction of all modes of transportation.

c) Identifying Users, their Issues and Providing Features for their Transit Access: Transit hub development should not only cater to multiple transit modes of travel but should also keep in mind the different types of users accessing the hub for their transit needs. These transit users range from able bodied people to physically challenged who suffer from different infirmities. Thus, the design guidelines should address to the issues of these various levels of users to achieve a universal and sustainable design. This will provide accessibility to all and increase the number of potential users. Hence, it is necessary to identify the issues associated with each type of user and provide supporting features in the design of the transit hubs. For example, the importance of tactile surfaces for visually impaired users. Some of the users have complained for it to be uncomfortable and hazardous, but are essential for people who are blind, hence the trade-off is worthwhile. Following are the list of features meant to facilitate easy movement of passengers with different impairments.

Why Intermodal Planning is Required?

- For energy efficient planning of transportation. This type of development uses multiple means of travel to complete a given trip which is optimal for different contexts and different user requirements.

Special Features For Different User Groups			
Group	Impairment	Physical aid(s) used	Features for station accessibility
Mobility 1	Physically fit	N/A	Loading/unloading area
Mobility 2	No use of legs	Wheelchairs, scooters	Clear path, loading/unloading areas
Mobility 3	Limited strength, endurance, dexterity, balance, coordination	Wheelchair, scooter, canes, crutches, walkers, seating, leaning posts, assistants	Clear path, loading/unloading area
Visual 1	Total blindness	Canes, dogs, assistants	Auditory, tactile surface, consistency
Visual 2	Partial blindness	Canes, dogs, assistants	Auditory, tactile surface, consistency, colour, contrast, lighting
Hearing	Deafness	Hearing aids	Visual displays
Cognitive	Impaired development, language	N/A	Simple language, consistency, symbols
Language illiterate	Impaired reading, speaking, lack of English skills	N/A	Simple language, symbols

Source: Journal of the Transportation Research Forum, Vol. 47, No. 3 (Public Transit Special Issue 2008)

- Not everybody uses every mode of public transportation, just like how not everyone needs the universal design features, such as curb cuts, ramps etc. However, most people will end up needing them sometime in their life. People will value having the different modes of travel in their community, even if they are not the ones currently using it. This provides certain benefit to them by balancing the travel demands per transit mode and therefore the value of multimodal planning can be evaluated from different perspectives.
- Even in rural areas, especially in India, where the distance from the transport hubs usually end up being miles away. These areas end up being disconnected from the major roads and public transport options. The same can overcome by the inclusion of multimodal transit hubs that will channelize transit modes to the remote corners of settlements. This will thereby fulfil the 2030 Agenda for Sustainable Development, which promises to 'leave no one behind'.
- The multimodal system offers variety of transport options with high degree of accessibility and well-connected transportation networks. This will help to overcome the automobile dependency.

- For example, Bangalore generating intermodal hubs. Bangalore Metropolitan Transport Corporation (BMTC) is a government agency that operates the public transport bus service in Bangalore, India.
Biyappanahalli : METRO + BMTC + AUTO / Taxi + Commuter Train + KSRTC satellite bus Stand + Pedestrian + Bicycle
Banahankari Temple: BMTC + METRO + Auto / Taxi + Pedestrian
Jayanagar : METRO + BMTC + Pedestrian + Bicycle + Auto / Taxi

4. Design elements and techniques

i. Passive Techniques

Daylighting: According to a number of studies, the average lighting energy savings from daylighting ranges from 24% to 80%. Adequate provision of daylight can be brought in a building through proper planning of windows in respect to the positioning and opening area. Daylight integration helps reduce dependence on artificial lighting (often the largest item of energy cost). In large scale buildings, it becomes really important to provide natural daylighting in order to save electricity consumption. It can be achieved through apertures like windows, skylights, roof monitors, light wells and clerestories. One of the drawbacks of daylighting is heat gain associated with it.

General guidelines:

- The sizes and locations of windows should be based on the position of the sun with respect to cardinal directions rather than their effect on the street-side appearance. It should aim at avoiding direct sunlight and glare.
- Openings allow only the entry of daylight inside the building. It is the ceiling shape that determines the distribution of the same. For example, use sloped or curved ceiling planes to achieve even distribution. Light shelves also help in even distribution of daylight when used in conjunction wide side light strategies.
- Direct sunlight and excessive brightness are never appreciated in case for natural lighting. It is important to filter the daylight with help of trees, plants, upholstery, translucent shades, light scattering glazing etc.
- Skylight or opening with 180 degrees view of the sky, are the most common daylighting technique. It is because they offer the most efficient means of bringing natural light inside the building.

Orientation: Orientation plays an important role for buildings aiming at achieving energy efficiency in their design. Orientation affects solar radiation, daylighting, and wind movement. Focusing on the warm and humid climatic condition like India's, orientation should be based on cooling as a predominant factor in the design.

General guidelines:

- A careful understanding of sun path and it's intensity along the different cardinal directions plays an important role in designing the building surfaces. For example, in Indian sub-continent, in the northern hemisphere experiences the usually sun path (rising from the east and setting in the west) but it's tilted towards the south side. Hence the south side receives more sunlight and heat. As the north orientation receives solar radiation with minimum intensity, it is preferred to have wider opening and longer surfaces facing the north. East and west receive maximum solar radiation during summers, hence it is preferred to avoid large opening and long facades in those cardinal directions.
- Orientation plays an important role with respect to wind direction. There is a need to establish the current wind flow to orient the building in the direction of the wind to maximize the wind flow and reduce the need for artificial cooling methods. This passive technique will reduce the dependence of the users on the energy consuming devices.

Landscaping: In architecture planning, landscaping becomes an important aspect of design. Spaces catering to large volume of people will end up with large amount of energy consumption to maintain the user comfort. Landscaping can be utilized at achieving passive design solutions. It is one of the most effective ways of altering microclimate for better conditions. These vegetative clusters help to provide buffer to sun, heat, noise and air pollution. It can also be used to divert the air movement and channelize it inside the building as a passive cooling method. Also, using native vegetation for landscaping will help in achieving low water consumption and will require low maintenance. For example, in India, planting on the west and south-west orientation of a building provides natural shade – thereby, reducing the need for cooling mechanism.

These are certain parameters of passive design that should be taken into consideration in the initial design stages to achieve a more sustainable design.

ii. Architectural elements: Urban inserts such as walkways, plazas and public parks and gardens are not seen in the recent city developments of the nation. For e.g. walkways induced with landscape which will provide natural shading and retail spaces will enhance user mobility and encourage the pedestrian flow. These open spaces benefit the pedestrians and non-motorized the most. These two activities are accessible to a large portion of the citizens and have positive social benefits with minimal environmental impacts. Encourage the society to opt for these sustainable modes of transportation.

iii. Advance Materials and Technology: With the advancement of technology and material innovation, the increasing demand of energy can be met through solar panels, piezoelectric tiles etc. There have also been developments in introduction to technology that will help in reducing its energy usage such as LED lighting, etc. Usage of such technology should be involved in the initial stage of design, to understand the steps that can be taken for an energy efficient development through active means and for cost estimations.

Piezoelectric: This smart material technique extracts, converts and stores energy from the environment when subjected to pressure. It is an energy harvesting technology, which has been recently becoming familiar with the built environment. It is important to understand that there is a need for efficient usage of these technologies to receive the best results. For example, transit hubs with thousands of users per day and the transit vehicle parking areas, such as bus parking area when designed with such materials will readily generate energy. This is due to the large number of users present for interaction with the material. Hence, reducing the stress on conventional resources.

Solar Panels: The benefits of solar panels are very evident in today's world. It has changed the way we gather and consume energy. The scale of infrastructure supporting the transit modes are huge and hence provide with large roof surface area to accommodate panels that can take up the energy load requirement. The energy load experienced in such public buildings is usually the highest as it runs for almost 24 hours. With the development of this innovation, there are now various other models to harvest solar energy through solar glass for windows and solar walls apart from solar roofing (now, conventional). This will help to utilize the different available surfaces without hindering the design.

LED Lighting: Another example in the innovation of advanced technology in reducing energy consumption. LED lighting is extremely energy efficient as they consume up to 80-90% less power than the previously relied on incandescent bulbs, As mentioned earlier, the transit hubs are operating for almost 24 hours, where the requirement of artificial lighting at every corner of the infrastructure development is a must (for safety). The LED lighting lasts six times longer than the other lighting types, hence reducing the requirement for frequent replacement. They also have better quality of light distribution, which means lesser number of light fixtures are needed to generate the same amount of light given off by fluorescents and incandescent lights. This will help in reducing the energy consumption and benefit the environment.

These technologies have paved path for a sustainable lifestyle and have encouraged the research and development in more technologies which will be beneficial for the environment and humans.

Conclusion: Transport infrastructure is one of the most important factors for a country's progress. With the increase in transportation systems through road widening, metro lines, increase in surface transit vehicles, there is a need of an infrastructure to support all these developments and enhance it's working. Therefore, at our end as architects, it is our aim to expand our knowledge into developing infrastructure facilities supporting multi-modals as well as energy efficient and sustainable designs. Development of these structures have a long-lasting effect on where it's built and how it functions on its immediate and expanded reachable surrounding. Hence, in this paper the idea was to achieve green solutions, right at the planning stage of the development, considering factors like site selection and multimodal system, which will help in efficient development of the rapidly increasing transportation sector. It also aims at

calling out for researchers, architects, planners and sustainable designers to fill in the research gap and elaborate more on sustainable methods and energy efficient solutions for passenger transport hubs.

Acknowledgment: I would like to express my deep and sincere gratitude to my guide, Amit C. Kinjawadekar, M.Arch., A.I.I.A., M.I.S.T.E., Professor at Faculty of Architecture, MIT, Manipal Academy of Higher Education for valuable guidance and encouragement throughout this research. He has taught me the methodology to carry out the research and to present the research works as clearly as possible. It was a great privilege and honor to work and study under his guidance. I am extremely grateful for all the help that he has provided me with.

I am extremely grateful to my family, for their love, prayers and care. They have always supported and me for my future.

My thanks go to all the people who have supported me to complete the research work directly or indirectly.

I would like to conclude by saying this paper has helped me in understanding the importance of sustainability and energy efficiency of transportation in the built environment. The paper has lent me a new perspective to the field of transportation and its development that can help to shape better cities and future.

References:

1. Singh, "Revenue from road Transport in India," Journal of Business Management & Social Sciences Research (JBM&SSR), vol. 3, no. 4, April 2014.
2. Pinna, B. D. Chiara and K. Pant, "Energy used by transport systems in India; the role of the urban population, sources, alternative modes and quantitative analyses," Energy Production and Management in 21st century, 2014.
3. "Transportation: India," 3 November 2011. [Online]. Available: http://web.worldbank.org/archive/website01291/WEB/0_CO-21.HTM.
4. L. Andrés, D. Biller and M. H. Dappe, "Infrastructure Gap in South Asia - Infrastructure Needs, Prioritization, and Financing," World Bank Group, South Asian Region, 2014.
5. India-California Air Pollution Mitigation Program (ICAMP), "Options to reduce road transport pollution in India," The Energy and Resource Institute (TERI), New Delhi, 2014.
6. (MoRTH), Road Transport Year Book (2009-10 & 2010-11), New Delhi: Government of India, 2013.
7. (MoRTH, Ministry of Road Transport and Highways, "Review of the performance of state road transportation undertakings (Passenger services) for April 2013," Government of India, New Delhi, 2015.
8. (N.T.D.P. Committee, "Urban transport," (MoUD) Ministry of Urban Development, New Delhi, 2012.
9. D. Pilla, "Energy Efficient Landscapes for Tropical Climate," Engineering Sciences International Research Journal, vol. 1, no. 1, pp. 1-4, February 2013.
10. N. Kaja, "Adaptation issues in urban settlements for climate change impacts," Engineering Sciences International Research Journal, vol. 1, no. 2, pp. 1-4, 2013.
11. Y. Kassem and H. Çamur, "Wind Power Vehicle Uses 3 Double C-Section Blades," Engineering Sciences International Research Journal, vol. 1, no. 1, pp. 1-3, February 2013.
12. G. Sun and S. P. Yew, "Sustainable Transport in Singapore".
13. B. Pradeep Kr Gupta, "Building Green CPWD's Green Vision for the Future The Prime Minister's Action Plan for Climate change came out with a "Mission for Sustainable Habitat", 2008.
14. R. Laing, E. Tait and D. Gray, "PUBLIC ENGAGEMENT AND PARTICIPATION IN SUSTAINABLE TRANSPORT ISSUES".
15. K. Kojima and L. Ryan, "Energy Efficiency Series 2010 TRANSPORT ENERGY EFFICIENCY Implementation of IEA Recommendations since 2009 and next steps".
16. H.-C. Chin, "Sustainable Urban Mobility in South-Eastern Asia and the Pacific Hoong-Chor Chin Regional study prepared for Global Report on Human Settlements 2013," 2013.
17. "Sustainable Building Design Manual Sustainable Building Design Practices".