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# Modelling the impact of Weather Conditions on Passenger Mobility

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# Introduction

# Motivation

- Transport system and passenger mobility is the backbone of any country's economic growth
- Transport sector share in Indian GDP – 4.2%
- Second highest role in world's GHG emissions which has doubled since 1970 and increasing at a faster rate than any other end use sector
- On the other hand, issues like the extreme weather conditions, climate change and GHG emissions have become a challenge for the betterment of urban transport mobility and passenger behavior towards the choice of travel mode
- Further, the frequency of extreme weather conditions has increased owing to global climate change (IPCC, 2014)
- Transport disruption due to meteorological conditions such as congestion, delayed trips or cancelled necessary travel for work and services is responsible for economic losses
- Disruption in regular traffic also responsible for safety issues, as it has reported that high temperature, wind speed and humidity leads to more accidents (Stern and Zehavi, 1990).

# Motivation

- As compare to logistic transport passenger transport is more vulnerable due to multiple reasons - occupancy level, role of public vs private transport, uncertainty, choices of transport, etc.
- Over the years, due to climate change and disruptions, resilient transport infrastructure become need of the hour for safety and better transport experience.
- The aim of the study is in line with the United Nations' Sustainable Development Goals (SDGs) 9 and 11 related to sustainable transport, specifically, SDGs target 11.2 states

  *"By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations."*

- This study addresses the impact of daily weather conditions on passengers' mobility in local trains, which are the backbone of Mumbai's transport system and standalone provide service to around 50% passengers of the city.

# Objective

- To analyze the role of weather conditions on passenger mobility in case of Mumbai Suburban Railways
- Three major weather conditions - temperature, humidity and wind speed, have been taken into consideration whereas passenger mobility is measured in the number of tickets sold through the major ticket booking systems
- The case of Mumbai suburban railways has been taken due to multiple reasons-
    - The climatic conditions
    - Geographical conditions & coastal region
    - high population density
    - Congestion
    - Asia's oldest suburban railway network
    - Economic significance of the city
    - Amongst the 14 major cities of India, the share of public transport is the highest in Mumbai - 78% in 2017 (Centre for Science and Environment, 2018)
- The fundamental research question is "How weather conditions affect the total passenger mobility of Mumbai suburb railways?"

# Literature Review

- In a nutshell, studies *(Misnevs et al., 2015; Bocker et al., 2016; De Sherbinin et al., 2007; Martin, 2005; Matzarakis, 2006; Tao et al., 2018)* have focused on rain and temperature as the significant weather conditions, which affect road passengers' mobility, especially in private vehicles.
- Few studies *(Arana, 2015; Kim and Macdonald, 2016; Brazil et al., 2017)* discuss about humidity, wind speed, and precipitation, as other weather factors may further affect passengers' mobility since the different atmospheric and meteorological conditions affect in various ways.
- Mirza (2003) highlighted that the extreme weather events can have a more adverse effect on the developing countries and suggested to be more focused on the creation of adaptive capacity rather than disaster management
- Inclement weather affects transit in many ways such as increased travel time, disruption in services, discomfort to the passenger, menace to safety and health (Miao et al., 2019).
- Bocker *et al.* (2016) in Netherland and Zhou *et al.* (2017) in China analysed people's reaction and behavior due to adverse weather condition and found behavioral factors play a significant role in transport ridership
- All the studies depict the high effect of weather on transport univocally.

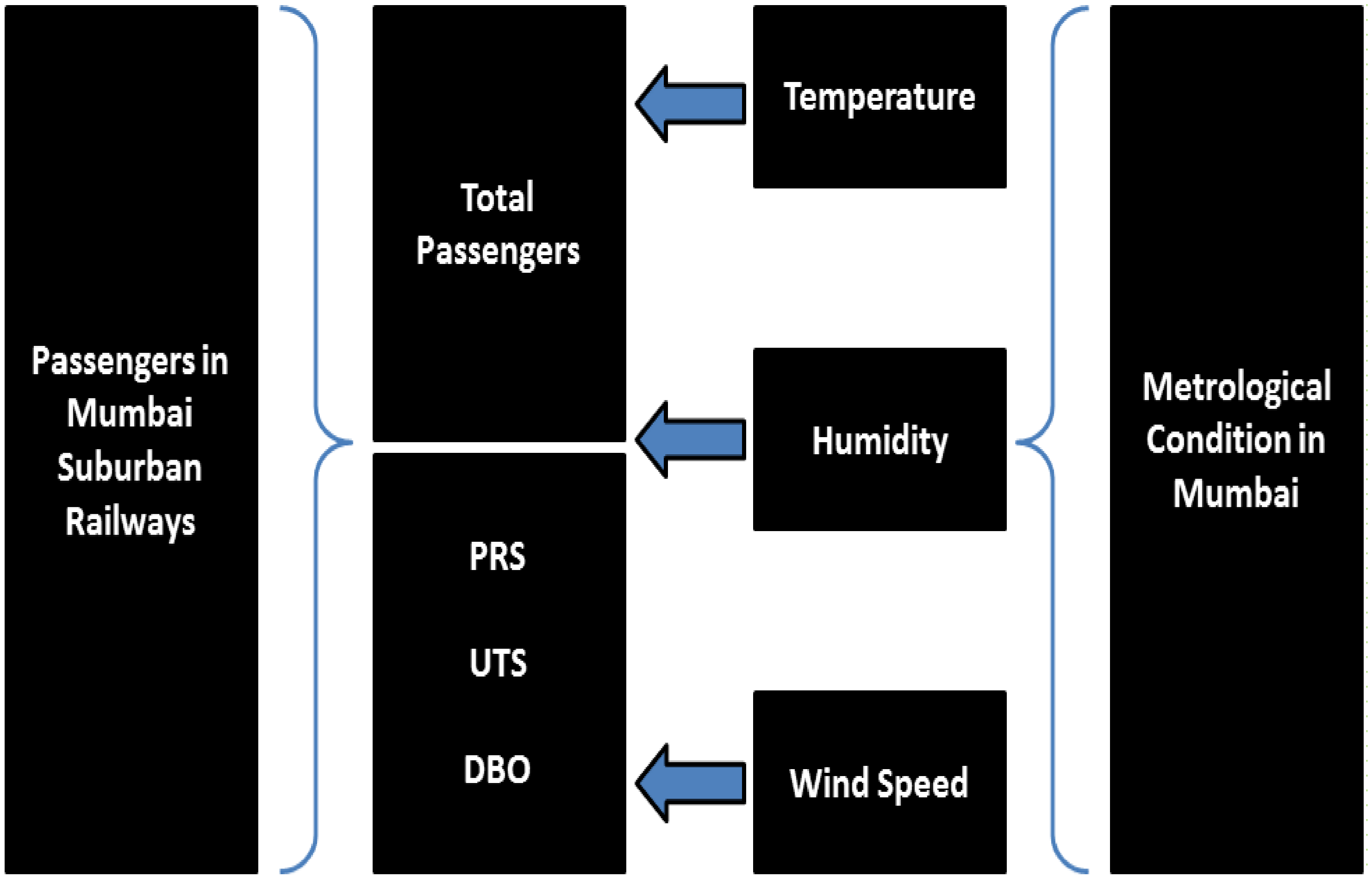
# Literature Review

**Research Gaps –**

- Most of the studies and research *(De Sherbinin et al., 2007; Zhou et al., 2017; Tao et al., 2018)* are focused on the demand side problems of the transport, but the supply side factors have not been discussed
- As per best of our knowledge, there is no study that considers the wind speed, humidity, and temperature as important factors in relation to passengers' mobility in city like Mumbai.
- The study used Wavelet Coherence model and Quantile-on-Quantile regression, which are rarely used by any study to analyze the association between meteorological conditions and public transport.

# Data, Model and Methodology

# Model & Theoretical Framework



# Theoretical Model

- The empirical model to be validated in this study is given as follows:

- $PSGR_{i,t} = f\left(MET_{j,t}\right)$

where, $MET_t = g(Temp_t, Humidity_t, Wind_t)$

# Data

- Data for passenger traffic movement collected from Mumbai Rail Vikas Corporation (MRVC)
- Daily data from September 2012 to March 2017.
- The number of passengers is given in lakhs of tickets sold via three major ticket booking systems to track passenger mobility.
- The three major ticket booking systems are Passenger Reservation System (thereafter PRS), Unreserved Ticketing System (thereafter UTS), and Directly from Booking Office (thereafter DBO).
- The weather information is obtained from the Indian Meteorological Department.
- The major variables used in the model are - Total Passenger (lakhs), Mean Temperature (Celsius), Mean Humidity (relative, measured in percentage) and Mean Wind Speed (kilometre per hour).
- Since it is the daily data, the seasonality and autocorrelation in the data have been taken care of.

# Methodology

- Quantile unit root test
  - Augmented Dickey-Fuller (Dickey and Fuller, 1979) and Phillips-Perron (Phillips and Perron, 1988) unit root tests and quantile autoregressive unit root test at the quantile level (Koenker and Xiao, 2004). The test also checks for stationarity on the conditional mean

$$Q_\tau^Y(Y_t|I_t^Y) = \mu_1(\tau) + \mu_2(\tau)t + \alpha(\tau)Y_{t-1} + \sum_{j=1}^{p} \alpha_j(\tau)\Delta Y_{t-j} + F_u^{-1}(\tau)$$

- Quantile cointegration test
  - Johansen (1991, 1995) cointegration test and at quantile level using quantile cointegration test by Xiao (2009)
  - Following Johansen (1991, 1995), we have checked the cointegration through the Vector Error Correction Model (VECM) for each pair of series by using following equation:

$$Y_t = \alpha + \beta Z_t + \sum_{j=1}^{p} \pi_j Y_{t-j} + \sum_{j=1}^{q} \gamma_j Z_{t-j} + u_t$$

# Methodology

- Multiple wavelet coherence
  - To check the co-movement and the directional associativity among variables
  - Wavelet coherence in a precise frequency realm classifies the zones, which are characterized by unpredicted and extensive deviations in the co-movement configuration of the assumed time series.
- Quantile-on-Quantile (QQR)regression
  - QQR approach following Sim and Zhou (2015)
  - The traditional quantile regression approach divulges the effects of one model parameter on the various quantiles of the other model parameter.
  - Further, a standard linear regression method appraises the role of a specific quantile of the control model parameter on the target model parameter.
  - The QQR method unifies both the methodologies to analyze the connotation between the quantiles of two model parameters

# Results & Major Findings

# Major Findings

- Model parameters are stationary after first difference, thereby confirming the integration of first-order among the model parameters
- Nonlinear cointegrating association among the model parameters
- The result of Wavelet Coherence portrays the negative association of aggregate passenger movement with temperature and humidity in the short to medium term, but mixed results are found in the long run
- In the case of a passenger-wind association, the results are mixed, and the co-movement is found to be both negative and positive in the short to medium term, whereas in the long run, the relationship is periodic.
- All the three variables, i.e., temperature, humidity, and wind, are found to be the leading indicators, which act as predictors for passenger movement in aggregate mobility analysis.
- The selected weather variables are serially correlated with passenger mobility.

# Major Findings

- In the case of three booking systems, both mixed and differential results are found, which shows that ticket services may have a different role. For example, people with monthly pass are more likely to travel irrespective of the meteorological conditions, whereas people who buy a daily ticket either from booking office or e-ticket, the decision of travelling by train may get changed.
- The results of QQR show that the rise in temperature leads to decrease in the total number of passengers travelled. However, the differential results at different quantile show that at the peak of temperature, people try to avail the services that reflect travellers' adaptability to the continuous increase in the temperature.
- Humidity has a positive relationship with passenger movement in all the quantiles. Nevertheless, the rise in passenger movement due to humidity is declining, which shows that initially, humidity may not have a powerful effect on passengers' movement but if humidity prevails for a longer time, people feel tired and dehydrated, thus reducing the increase in passengers' movement.
- The Passenger-wind relationship shows a periodic fluctuation in the impact. The QQR results are more segregated and vary across the three booking systems.
- The results show that the impacts of extreme weather conditions tend to converge for aggregate passengers, whereas the impacts largely differ based on various ticket booking systems.

# Conclusion

# Policy Implications and Contribution

- Implications for other public transport and suburban transport system in other cities with homogeneous climate and geographical conditions.
- In addressing the disruptions of the timely reaction of the passengers' travel demand because of the adverse meteorological conditions.
- The adaptation to different practices for dealing with adverse climate may be helpful in passengers' movement or traffic shift during unpleasant windy, warm and humid atmosphere. It is essential to manage potential amenities and improve operational efficiencies such as more AC coaches, seating facility in the shelter, shedding, shutter services, elevator and consumer-friendly other additional services.

# Future Research

- The findings can be extended for the cities with similar geographical and climate conditions.
- Future research can be done to analyze the weather effect on other modes of transport such as buses, taxis, private vehicles, etc. in Mumbai as well as in India.
- The nudging behavioral changes for adaption of public transport by providing user-friendly support infrastructure during extreme weather conditions may have a substantial effect in retaining passenger ridership.
- The more comprehensive framework, including all transport mode and seasonal fluctuation, can also be considered in future studies.

# Limitations

- Rain effect is prominent only during the rainy season, which consists of four months in a year. Further, there are few studies (such as Gupta, 2007 and Patankar *et al.*, 2010) that have already discussed the role of rain in the case of Mumbai.
- Segregation in terms of ticking system

# Questions/ Suggestions/Feedback

# Thank you