

An Empirical Assessment on the Transportation Sustainability Indicators and their Impact on Economic Productivity

Adeeb A. Kutty, Zehra Yetiskin, Muth M. Abraham, Mahmoud A. Nooh

Engineering Management Program
College of Engineering, Qatar University
Doha, Qatar

aa1704810@qu.edu.qa, zy1513155@qu.edu.qa, ma1901095@qu.edu.qa,
ma1204797@qu.edu.qa

Murat Kucukvar, Galal M. Abdella

Mechanical and Industrial Engineering Department
College of Engineering, Qatar University
Doha, Qatar

mkucukvar@qu.edu.qa, gmg5005@qu.edu.qa

Abstract

Sustainable transportation has been traditionally acknowledged as an accelerating factor in achieving economic productivity. This paper attempts to frame a methodology to study the sustainability of the transportation sector and economy, based on selected key transportation sustainability performance indicators. Previous findings in the literature support the contribution of transportation performance indicators towards achieving economic productivity. This paper examines the dependency of key transportation sustainability indicators on United States economic productivity. The econometric model consisted of performance indicators: a portion of the budget devoted to transportation, per capita traffic congestion delay and, efficient pricing for transportation as the independent variable with per capita GDP as the dependent variable. Three hypotheses were validated using multiple linear regression analysis, with statistical software Minitab 17 and visualized using Tableau 10.0.9. A predictive and what-if analysis was also conducted. The results show a strong correlation between the indicators chosen, highlighting their role in contributing towards overall sustainability.

Keywords:

Economic productivity, transportation sustainability, a portion of the budget devoted to transportation, per capita traffic congestion delay and, efficient pricing for transportation

1. Introduction

United States (US) being the world's largest stable economy and the leading consumer market recorded a transport and logistic business cost of around 1.8 trillion USD, and its contribution to real GDP (Gross Domestic Product) in 2019 Q3 has seen a rise of 0.09% (UNCTAD 2012). The data published by the US Environmental Protection Agency (EPA) in 2017 shows that the sector's fossil fuel burning vehicles are accounted for 29% of greenhouse gas emissions in the states. By 2030, the "eco-city" concept will become a reality in the US, and the face of transportation will be changed immensely by technology, keeping hold of the zero-emission perspective.

Studies have shown remarkable growth in the area of transportation sustainability and resilience around the globe. Sustainable transportation systems are crucial in meeting the economic efficiency and social demand of a country's population and thus minimizing negative impacts on the environment (Keeling and Mooney 2011). Typical expenditure on transportation sector is 2-13 percent of the annual budget (UNCTAD 2012), and transportation is considered as a significant element in sustainable development goals of 2030 and thereby achieving the present and future needs (United Nations 2008). Sustainable transport has to be highly encouraged, and it is almost difficult to tackle climate change without establishing sustainability. Transportation is accountable for 23% of global emissions (IEA 2018).

The close and quantitative relationship between transportation indicators and economic productivity has been focused on by many researchers for long. This paper also aims to gauge economic productivity against indicators such as a portion of the budget devoted to transportation, per capita traffic congestion delay, and efficient pricing for transportation. Hulten and Schwab (2019) evaluated the association between transport investment and economic productivity by means of growth regression models and another analysis conducted by researcher Batina (1998), who adopted Vector autoregression (VAR) models on macroeconomic variables. In the VAR model, economic growth is explained using historical data of variables and proceed with testing for multivariate autocorrelation (Pacífico, 2019). Investment in efficient transportation infrastructure benefits the economy by enhancing market accessibility, ensures stability in geopolitical conditions, employment, fewer emissions, easy mobility, and connecting communities, and it can be measured as a share of GDP. European Commission reported insufficient levels of transport investment during the global economic crisis; GDP remained at 2.7% in 2016, which was the lowest in 20 years; thus, slowing the economic convergence (EIB 2018). Canning and Pedroni (2004) stipulate economic theory as there is an optimal level of investment that maximizes the growth rate, and further investment above this point can trigger a negative effect in overall growth. Dedicated Freight Corridor (DFC) is a major initiative implemented by the government of India for transport infrastructure to cater to the needs of India's economic growth, which is rapidly increasing and also gives an add on advantage in developing the regional economy. The project aided in transforming the transportation sector by increasing the dependency on rail transport as an energy-efficient, eco-friendly mode of transport, resulting in a low carbon footprint. Expectations are that during the first 30 years of implementation, savings of more than 450 million tons of CO₂ could be registered.

Traffic congestion is a dynamic complex problem resulting in undesirable events such as increased traveling time, air pollution, wasted wages, etc. To better understand the dynamics of traffic congestion related problems, see Arnott & Small, (1992). Congestion delay per capita is considered as a congestion indicator, and only recurring congestion is incorporated into the delay measure (Lomax et al., 1997). Per capita traffic congestion delay favors economic productivity, and congestion delay can be easily rectified by improving the current infrastructure, improving the use of technology (AI), and adapting to a high level of traffic congestion by opting for alternative modes of transport.

Statistics indicate that the transportation industry accounts for 5% of GDP (European Commission 2019). Transportation pricing involves major elements such as logistics cost, road tax, import duties, customs duty, revenue, gasoline/fuel indicator, pollution risk pricing, off-loading costs, toll, etc. (IEA 2018; United Nations 2016). Transport pricing is highly dependent on infrastructure and the geographical position of economies; e.g., landlocked countries trade less compared to the costal countries, whereas several policy regulations are in place to improvise the trade; by transportation connection between neighboring countries and border trade (Limão and Venables 2001). Thus, investigating more in the area of transportation sustainability and its contributing factors can definitely bring about an increase in economic productivity, where economic productivity is gauged using per capita GDP measures. This justifies the rationale for undertaking this area of research. Establishing a concrete relationship between the GDP per capita and possible indicators for performance measurement in the transportation sector can bring promising growth to the industry and country as a whole.

2. Research Methodology

The impact of key sustainable transport performance indicators on economic productivity has been explored using empirical assessment techniques. A correlation study to understand the strength of the predictor variables on economic productivity will form the basis of the analysis. The research question sets out to merit a detailed argument on "What are the significant impacts of sustainable transportation on economic productivity at a national/regional level?". The research objectives in conducting an estimation of the three exogenous variables chosen within the scope of the research-namely; the portion of the budget devoted to transportation (x_1), per capita traffic congestion delay (x_2), and efficient pricing for transportation (x_3).

A multiple linear regression (MLR) model is used to analyze the impact of the chosen explanatory variables on economic productivity by monitoring the variations in these variables (Abdur Rouf et al. 2018; Abdella et al. 2019-a). A proxy variable, *per capita GDP growth* is used as an endogenous variable (Y) to understand the economic productivity. The explanatory variables chosen are of great significance in the field of transportation sustainability (Hozo et al., 2005). Table 1 shows the statistical hypotheses that form the basis of our analysis plan. An ordinary least square (OLS) regression analysis model is used to validate the formulated hypotheses.

A predictive analysis using the data-driven intensive simulation model, the *What-if* analysis is also used to study the behavior of the United States transportation system under the assumed hypotheses (Table 1). The analysis helps to acquire a better insight into how changes in selected key transport performance indicators impact economic

productivity with reference to the simulation model.

Table 1: Research hypothesis

SL. No	Symbol	Hypothesis
1.	H1	The portion of budgets devoted to transportation is a significant factor contributing to the nation's economic productivity and has a moderate to strong correlation with economic productivity
2.	H2	The impact of per capita congestion delay on economic productivity is positive and statistically significant
3.	H3	Efficient pricing for transportation has a significant correlation with economic productivity

3. Results

3.1 Correlation and Regression analysis

A descriptive statistics summarizing the measures of central tendency- mean (μ) and median (\tilde{x}); measures of dispersion- variance (σ^2) and standard deviation (st. dev.); and, minimum (min) to maximum (max) value for the chosen transportation sustainability variables used in our regression model can be seen in Table 2. If the μ and \tilde{x} values in a regression model tend to be approximately close to one another, then the data sample is assumed to be normally distributed (USDT 2009). While observing the mean and median values, we can see that all the values tend to be very close and nearly equal to one another, summarizing the fact that all the selected variables for our study are normally distributed.

CUSUM's test for structural stability was performed to test the structural stability of the selected variables in our regression model. Here, the null hypothesis (H_0) is that the parameters are structurally stable to the alternative (H_A) that they are not structurally stable.

$$H_0 = \text{Parameters are structurally stable} \quad (1)$$

$$H_A = \text{Parameters are not structurally stable} \quad (2)$$

If the test crosses even once the 95% confidence band, the coefficients are not structurally stable. While, if the test does pass the 95% confidence band at some time, there is a structural change up to or including that point. To better understand the test, check Ploberger & Krämer, (1992). From Fig. 1, we observe that the red line does not cross the 95% confidence band. This means that the coefficients are structurally stable. Hence, we accept the null hypothesis.

Table 2: Descriptive Statistics

Variable	Mean	St. dev.	σ^2	Min	Med- \tilde{x}
Y	48.00	17.78	316.00	26.00	40.00
X1	53.36	12.68	160.87	34.19	55.11
X2	153.46	17.77	315.63	122.17	153.74
X3	183.58	4.87	23.69	175.09	183.09

Source: Authors calculations using the software Minitab 17

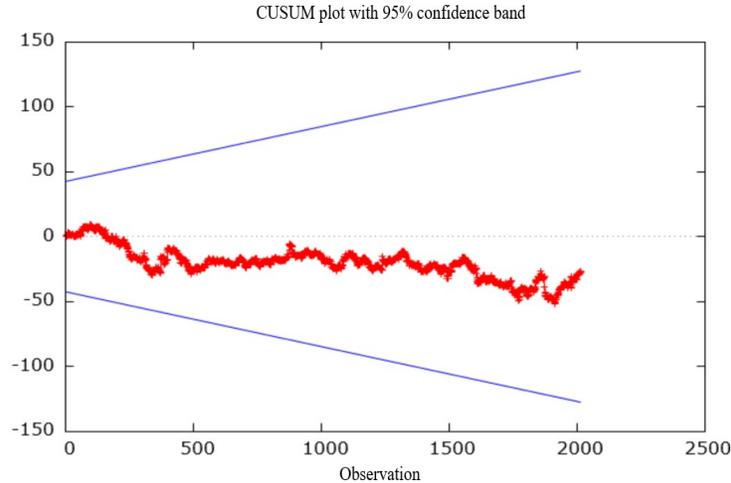


Fig. 1. CUSUM's plot with a 95% confidence band for the regression model

A Pearson correlation analysis was also conducted to test whether the correlation coefficients are statistically significant or not (Table 3). To better understand if there is significance between the coefficients, a p-value less than or equal to 5% ($\alpha = 0.05$) is taken into account. Here, the null hypothesis (H_0) is that the correlation coefficients are statistically significant, while the alternative hypothesis (H_A) is that the coefficients are insignificant.

$$H_0 = \text{The correlation is significantly different from zero} \quad (3)$$

$$H_A = \text{The correlation coefficients are statistically insignificant} \quad (4)$$

By observing the p-values of the relationships between the selected macroeconomic indicators from Table 4, we can see that all the p-values for the correlation are less than the 5% significance level. This gives us conclusive evidence to accept the null hypothesis, i.e., the correlation is significant. The strength and direction of the relationship between the selected indicators are observed in Table 4. Pearson's r -value indicates a moderate to a strong relationship between the variables in a positive direction. By applying the general rule of thumb, we can see that the values of the correlation coefficients are very close to +1 (range -1 to +1). This indicates that there exists a moderate to the strong positive linear relationship between the macroeconomic indicators.

Table 3: Pearson correlation and p-value between the Macroeconomic Variables

Variable	Y	x ₁	x ₂	x ₃
Y	1	0.740 0.004	0.748 0.002	0.813 0.001
x ₁	0.740 0.004	1	0.610 0.006	0.531 0.019
x ₂	0.748 0.002	0.610 0.006	1	0.831 0.001
x ₃	0.813 0.001	0.531 0.019	0.831 0.001	1

Source: Authors calculations using the software Tableau 10.0.9

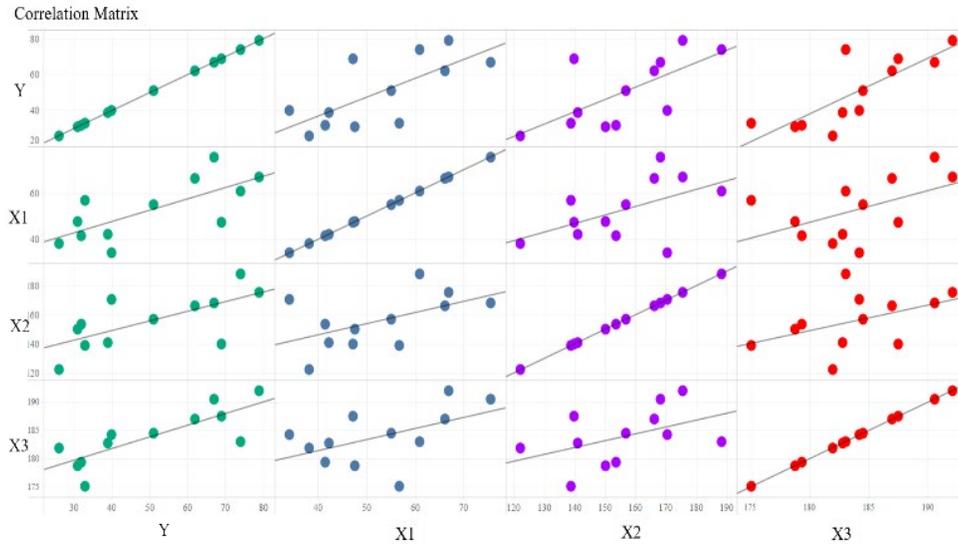


Fig 2. Correlation matrix based on r and p-value using Tableau 10.0.9

An ordinary least square (OLS) regression analysis was performed on the set of data to further validate our hypotheses. The per capita GDP was chosen as the response variable (Y), and the portion of the budget devoted to transportation (x_1), per capita traffic congestion delay (x_2), and efficient pricing for transportation (x_3) were chosen as the predictor variables ($X_i, i=1...3$). For the estimation, all the data from the United States Bureau of Transportation Statistics and OECD dataset for a period from 2000 till 2018 were used.

The results of the OLS analysis are shown in Table 4. The p-values for all the response variables indicates that the key transportation sustainability indicators are statistically significant. The coefficient of determination value 84.70% (R-sq), is also apparently high. The fitting equation for the regression model in Table 4 is:

$$Y = - 353.2 + 0.404 x_1 + 0.309 x_2 + 1.810 x_3 \quad (5)$$

Table 4: Regression model summary

Variables	Appearance			
	Coefficient	T-Value	P-Value	VIF
Constant	- 353.2	- 4.63	0.000	-
x_1	0.404	2.15	0.048	1.76
x_2	0.309	2.30	0.036	1.76
x_3	1.810	3.95	0.001	1.54
Dependent Variable: Per capita GDP				
WSS residuals	: 14.5784			
R-Sq Value	: 0.8470			
Adj R-Sq Value	: 81.64 %			
Bayesian Info Criterion	: 1.6531			
Durbin-Watson Statistic	: 2.10132			

Source: Authors calculations using the software Minitab 17

A test for multicollinearity among the selected indicators in our regression model was also conducted. As seen in Table 4, the VIF for x_1 , x_2 , and x_3 are 1.76, 1.76, and 1.54, respectively. This indicates an extremely moderate correlation among the explanatory variables. By applying the general rule of thumb, a VIF value between 1 to 2 indicates a negligible correlation and can take the assumption that there are nearly no multicollinearity issues among the indicators. Thus, concluding the fact that multicollinearity is of no concern in our regression model.

The relationship between economic productivity and key transportation sustainability performance indicators is evaluated using the correlation and multiple regression analysis and is found to be appreciably strong. Hence, all the three hypotheses that stood as the basis of the study were validated.

Table 5: Hypothesis validation

Hypothesis	Status
H1	Valid
H2	Valid
H3	Valid

3.2 Predictive and What-if analysis

The correlation analysis is of great importance for understanding the relationship between the variables of the model (Ghadban et al. 2018; Kucukvar et al. 2019; Abdella et al., 2020). The correlation and regression analysis performed help in identifying the impacts produced by the introduction of key performance indicators in the econometric model and gives a better insight on the explanatory power of the selected indicators towards achieving economic productivity. Predictive analytics helps in identifying the problem areas beforehand and helps to divert the area of focus for better problem-solving—a predictive and what-if analysis based on scenarios were conducted for the econometric model.

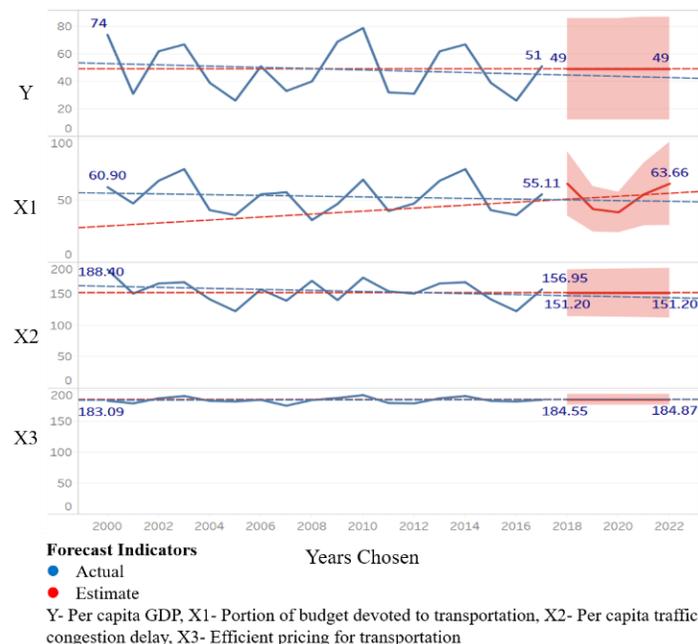


Fig. 3. Trend analysis plot for each variable used in the regression model performed using Tableau 10.0.9

The results for the predictive analysis for each dependent and independent variables used in our regression model has been presented in Fig.3. The analysis has been performed five years into the future, setting a 95% level of prediction interval and demonstrated the results with a good quality level, which indicates how well the forecast fits with actual data. In the trend analysis plot, for each per capita GDP (Y), per capita traffic congestion delay (x_2), and efficient pricing for transportation variables (x_3), the fits follow data closely, which determine the forecasts are probable to be accurate. It is apparent that for the variable “portion of the budget devoted to transportation (x_1)”, the fit shifts away at the at the end. In this case, gathering more data on the variable will determine if the trend is consistent over a long time period.

Fig.4 illustrates the potential outcome in Per Capita GDP (Y) based on changing the parameter x_1 . Seven units of change in x_1 have an effect of an increase in 5.18 units, which supports the correlation between x_1 and What if Y. Since the expected max value for What if Y is 75.88 by considering the distribution of values within data, the higher value can be partially explained by the correlation with Y itself.

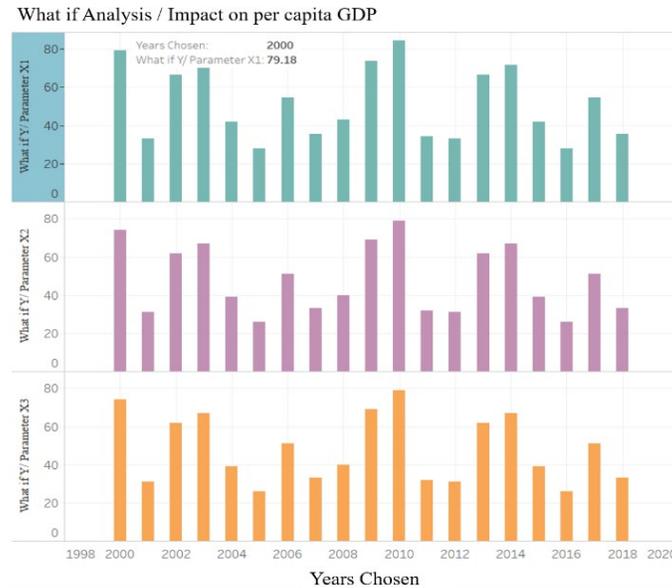


Fig 4. What-if analysis for the impact on per capita GDP by changes in the portion of the budget devoted to transportation using Tableau 2019.4

Fig.5 shows the scenario effect on Per Capita GDP by changing the variable x_2 for 12 units for the year 2003. Considering the distribution of the data, the expected value for What if Y is to be between 33.33 and 79.43, which is within the range of natural variation.

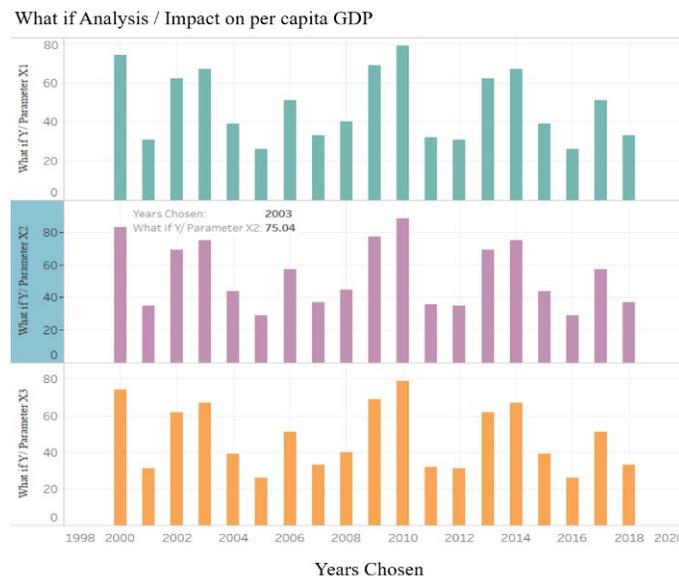


Fig 5. What-if analysis for the impact on per capita GDP by changes in per capita traffic congestion delay variable using Tableau 10.0.9

When considering Fig. 6, we not that a 10-unit change in variable x_3 sets a value of 28.60 for What if Y. When the distribution of data is considered, the value in this scenario for What if Y is expected to be 29.76 at the lowest level. The lower value is explained by correlation with Y.

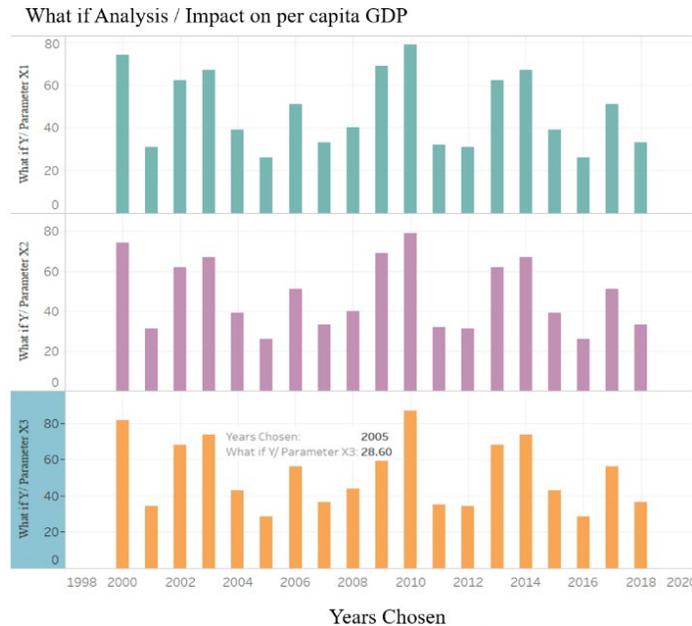


Fig 6. What-if analysis for the impact on per capita GDP by changes in variable x_3 using Tableau 10.0.9

4. Discussion of Results

The study presented in this paper attempts to methodologically enhance the existing knowledge related to the impact of economic productivity on key sustainable transport performance indicators. The MLR coefficients used in the analysis were estimated using the OLS model. All the statistical analyses were performed using the data analysis software Minitab[®]17 and, all the data visualizations were performed using the software Tableau 10.0.9.

The prime focus of the study was to create a fit regression model with economic productivity as the response variable and three continuous predictor variables as a portion of the budget devoted to transportation, per capita traffic congestion delay, and efficient pricing for transportation. The results show that the indicator, efficient pricing for transportation, holds the strongest impact on economic productivity with a coefficient value of 1.810, followed by a portion of the budget devoted to transportation (co-efficient = 0.404) and per capita traffic congestion delay (co-efficient = 0.309).

Analyzing the R-sq value that equals 0.8470, we can see that nearly 84.70 % of the observed variations in economic productivity is explained by the key sustainable transport performance indicators in the model. This highlights the fact that nearly around 15.3 % of the movements that contribute to economic productivity is still not explained by the indicators that were used in our model. When analyzing the Durbin-Watson Statistics, we observe a value of 2.10132, a value very close to 2. By a general rule of thumb, any statistic value between 1.5 to 2.5 translates to a lack of collinearity with the residuals. This concludes the fact that the errors have no autocorrelation.

The predictive analysis result for the indicator portion of the budget devoted to transportation (x_1) is at 63.66 level by 2022. The last five years of actual data and the estimated values for the next five years identify a changing trend which highlights that the other indicators related to the specific indicator should be taken into account to research further for the reasons to identify low and high changes in the actual and the estimated trend. Since the transportation assets constitute one of the most important economic resources of the government, the value and the investment in transportation demonstrate a strong relationship with Per Capita GDP (0.7399565).

Per capita traffic congestion delay (x_2) has a strong positive correlation (0.74794623) with per capita GDP. Reducing congestion leads to lower transportation costs and contributes the national economic productivity as a whole. The last five years' actual data for per capita traffic congestion delay show a trend changing between 122.173 to 168.257.

The predictive analysis revealed that a slight increase occurs for the next five year and reaches to 151.20 by 2022. It is crucial to note that reducing congestion and improving reliability by focusing on first at the operational level, will provide outputs to tactical level decisions in order to support other important indicators affecting economic productivity. The portion of the budget devoted to transportation (x_1), which also has a strong correlation with congestion (0.60998308), requires professional expertise in the management level and will be highly affected by the congestion management phase.

Efficient pricing for transportation (x_3) provides economic benefits and sustainable growth for the economy. This factor on economic productivity could well be explained by the high correlation (0.81281364) between the indicator and Per capita GDP (Y). The efficient pricing policy for the last and next five years remains stable (151.20). The most striking result to emerge from this data is that while ensuring a stable, efficient pricing policy, the government should make sure that the prices must reflect those other relevant indicators which are valued more than their social cost. The estimated model thus satisfies the 95% confidence band for all the key macroeconomic indicators used in the study. All the variables selected to hold a positive impact on economic productivity in the United States and were found to be statistically significant. The model explains nearly more than three-quarters of the variations in the country's economic productivity.

The MLR analysis, predictive, and what-if analysis used in this study were based on a set of longitudinal data for the key macroeconomic variable and transportation sustainability indicators over a span of 18 years thus, helping us to provide a better econometric picture of the United States Transportation sector.

5. Conclusion

The study emphasizes the influence of prime contributing factors in promoting economic recovery and points out areas of growth. Investments in the transportation sector have tackled down serious consequences related to health and quality of life. Planned investments in facilitating easy access roads, solid and liquid waste treatment facilities, reducing transportation impacts on the environment and better educational institutions that generate a talented workforce promotes a boost to the economic productivity (USDT 2009). Thus, the linear statistical relationship established in the study between economic productivity and a portion of investment devoted to transportation is meant to better support the hypothesis.

Enticing positive adaption in transportation planning helps in eradicating transport congestion delays to a great extent (Luten, et al., 2004). The impact of per capita traffic congestion delay on economic productivity is linear. This might often seem counterintuitive based on the assumption that "how can inhabitants be more productive when muddled in traffic congestion?". Cities provide better accessibility for its citizens in terms of better jobs, life prospects, quality services, etc., thus increasing the demand for travel. Such a demand can often lead to congestion issues and a positive -level shift towards choosing an alternative mode of transportation (Chatman and Noland 2013; Wheaton 2014). Thus, faltering economic productivity due to the per capita congestion delay is long dispelled.

Efficient pricing at a certain quality for transportation services estimates a linear relationship with economic productivity, as seen from our analysis. Optimal pricing strategies also lead to a reduction in traffic congestion by the marginal use of transportation infrastructure (Estache and Trujillo 2017). Improvements in pricing strategies can have a drastic impact on urban growth, thus creating a balance between the tri-dimensional pillars of sustainability.

The transportation sector thus can be seen as a crucial element of the economy and the indicators used as a building block for productive outcomes. For future works in this field of research, the authors recommend the extension of feature selection techniques such as Ridge and least absolute squared shrinkage operator (LASSO). These models have the advantage of selecting the variable that best describes the model variability; see Abdella et al. (2019-b); Assaf, Tsionas, and Tasiopoulos, (2019); Suhail, Chand, and Kibria, (2019). Other regression techniques for social and environmental factors that contribute towards sustainable outcomes can be used while broadening the selection of indicators. Increasing the data sample can help in a rigorous understanding of the influence of the selected indicators against the regressor.

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Biographies

Adeeb A. Kutty is an accomplished professional with a bachelor's degree from University of Calicut, India, in Electrical and Electronics Engineering and a master's degree holder in Technology and Engineering management from Universitat Rovira i Virgili, Tarragona, Kingdom of Spain. He is currently doing his PhD in Engineering Management and works as a Graduate Teaching and Research Assistant in the Department of Industrial Engineering at Qatar University. His area of research interest include sustainability and systems engineering, smart cities and regional development, Electric vehicles, transportation and project management.

Zehra Yetiskin received her master's degree in Business Administration-MBA from Istanbul Kultur University, Turkey and bachelor's degree in Industrial Engineering from Sakarya University, Turkey. She holds 12+ years of industrial experience in Supply chain management, business process improvement, quality management, logistics and operations and, change management. She is currently doing her PhD in Engineering Management at Qatar University, Doha-Qatar. Her area of research includes but not limited to lean management, agile supply chain, heuristic and metaheuristic optimization and quality control applications.

Muth Mary Abraham was awarded her bachelor's degree in Chemical Engineering from Government Engineering College, West Hill-Calicut, India. She is currently working as a business support coordinator in Muntajat marketing and distribution company, Qatar and is pursuing her master's degree in engineering management at Qatar University, Doha-Qatar. Her research spans across areas such as simulation and Modeling, and Human Factors and Ergonomics.

Mahmoud. A. Nooh received his bachelor's degree in Chemical Engineering from Swansea University, United Kingdom. He is currently working as a Senior Planning Engineer in Qatar Petroleum, Doha-Qatar. He is currently studying his master's in engineering management from Qatar University, Doha-Qatar. His research interest includes project management, manufacturing system design and system simulation.

Dr. Murat Kucukvar serves as an Associate Professor in the Department of Industrial and Systems Engineering at Qatar University. He has held the positions of Industrial and Systems Engineering Graduate Program Coordinator, Member of the Board of Directors in the College of Engineering and Natural Sciences, International Programs & Erasmus Coordinator, and Member of the Quality Management Commission in Istanbul Sehir University, Turkey. Dr. Kucukvar is an expert in the fields of Sustainable Cities and Societies, Sustainable Operations Management, Supply Chain Management and Transportation, Modeling and Simulation, Multi-Criteria Decision Making and Optimization.

Dr. Galal M. Abdella serves as the Assistant Professor in the Department of Industrial Engineering, College of Engineering, Qatar University. He is currently the coordinator of the Engineering Management Program at Qatar University. His research area has always been centered on utilizing mathematics and advanced statistical data analysis for high dimensional data processing, circular economy and food security, modeling and simulating rare events, quality data modeling and analysis, and project resource management.