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Abstract

Pakistan is one of the third-world countries where technological adaptation is in its initial stages, with several initiatives/projects in the pipeline and others awaited to accomplish for setting the benchmark in their respective areas. Similarly, to meet the dire need for time, the communication sector is also working on advancements and automation in transportation by implementing Intelligent Transportation System (ITS) along its major highways. However, shifting from traditional to modern practices in the transportation sector has shown minimal progress; it has proven a tiresome and laborious process, putting the interest of foreign investors at stack as well. This research, therefore, is meant primarily to elaborate on the Barrier factors hindering the Effectiveness and Development of the Intelligent Transportation System (ITS) Projects in Pakistan and their addresses prudently by measuring their impact in terms of system, function ability, and potential benefits. The analysis will be made using the Partial Least Square technique of the "Structural Equation Modeling" method (PLS-SEM) by constructing and analyzing the data collected from various sources with the help of a questionnaire; the reliability will be established using the Crone batch alpha technique. The results demonstrated remarkable dependence on the Effectiveness & Development (E&D) of ITS on the failure of Policy & Governance, Financial and Technical drought, lack of Exposure and Infrastructure integration, and Rapid urbanization.

Keywords: Intelligent Transportation System, Green Mobility, Sound infrastructure, Smart Mobility, Geographic Information System, Internet of Things, Project Risks.

1. Introduction of the Study

Transportation has been one of the key fundamental elements in humans; it ensures the conveyance of people, animals, and goods from one location to another. Following the ages of domesticated animals and wheel carts to current robust cars and airplanes, the

transportation sector has shown an enormous continuous evolution in infrastructure development and effectiveness on the human economy and environment. The development of the transportation Infrastructure has been categorized into four (4) significant clusters by the researchers.

The first wave of transportation development started between 1950 to 1980 with the worldwide construction of freeways, thus providing a new perspective in the transportation sector, which also motivated Engineers and researchers at the same time to study the characteristics of new transportation models and develop ways of operating and managing the expanding network (Weiner, 1987). However, due to the limitation of experimental and survey data, most developments were based on ideal assumptions, and the models were thus empirical and static.

The second wave of development within the transportation sector encompasses the 1980s to 2000. It is considered the era of dynamic, statistical, and disaggregated transportation models developed by exploring additional capacity from the existing infrastructure to balance the supply and demand chain (Meyer & Miller, 1984). This era was witnessed by the effective use of Information Technologies in the field of transportation, thus paving the way for the legislation of the transportation sector (Gage & McDowell, 1995) and the emergence of the Intelligent Transportation System.

Ran, Jin, Boyce, Qiu, and Cheng (2012) figured out the third and the current wave of the transportation sector from 2000 to near future decades as an era of ITS dominance where communities will be more attracted to green and environment-friendly mobility by having reliable connectivity between all elements (human, vehicle, and infrastructure) of transportation stream.

Intelligent Transport System ITS reduces complexity faced in the transportation system, such as high accidents rate, traffic congestion, traffic & carbon emissions, air pollution, etc. Hence, virtual technologies integrated by researchers to solve this problem globally in reducing risks, accidents rate, and traffic congestion; researchers also analyze that these technologies, on the other hand, increase Safety and reliability, increase travel speeds, and result in smooth traffic flow. As per the figure of the United Nations, 68% of the population around the Globe by 2050 will be based on an urban lifestyle; thus, eventually resulting in the exhaustion of capital and existing infrastructure will be flocked. Following this, it is often claimed to be the core element in constituting a typical "smart" city.

The fourth wave of the transportation sector, however, is characterized by (Ran et al., 2012) as a highly dependable, highly integrated, fully automated, and optimized with the latest technologies, including cloud computing and Information Communication Technologies (ICTs) that would be the motive in the way of promoting ITS. Intelligent Transportation Systems (ITS) is the system of applying diverse technology to make transportation environmentally friendly without bringing any alteration to the existing system. Here is the summary of enabling technologies in Intelligent Transportation Systems that can bring reliability to the ITS system, which include Wireless communications, Computational technologies, Floating car data/floating cellular data, Sensing technologies, Inductive loop detection, Video vehicle detection, Bluetooth detection. The emergence of these technologies improves transportation conditions, Safety, and services by integrating current and growing communication technologies (Qi, 2008)

This study, therefore, aims at studying the factors that are proving to be significant barriers to implementation and their impact on the effectiveness & Development of ITS in Pakistan. We have an immense network of highways and motorways comprising 15000 km long, with millions of daily Commuters and costly installed assets all along the alignment. However, these immense networks of highways are proving to be insufficient with every passing day due to an ever-increasing number of vehicles; the only viable way to cater is the adaptation of ITS instead of investing in constructing new highways parallel to the existing ones. Advancements in electronics also led to the need for new embedded systems with more sophisticated software applications, such as model-based process control, artificial intelligence, and ubiquitous computing. Road traffic congestion is one of the most challenging issues the urban traffic system faces daily (Ran et al., 2012). This traffic congestion impacts the traffic flow in many ways. Among these impacts, the delay in emergency response is the most critical as it might involve a cost in human deaths and injuries, such as in cases of accidents, fire, and terrorist attacks.

An extensive transportation infrastructure has been built under China Pakistan Economic Corridor (CPEC) flagship, comprising almost 7000 km of state Highways, Motorways, and Expressways, and uplifting local arterials. However, despite the enormous addition to the network in the form of blended state-of-the-art Tunnels, bridges, and Culverts, implementing the Intelligent Transportation System on the CPEC alignments has not proved successful in the demography of Pakistan. The system initially installed on some of the motorways has resulted in an enormous loss to the state treasury. It has faced many critical

hindrances in the implementation and operations stage despite its dozens of benefits ranging from infrastructure lifecycle and human Safety to economic commutation and revenue enhancement.

Nations across the Globe are adapting to the massive shift in transportation regimes using e-mobility to contribute to biodiversity and aid to climate change. Implementing Intelligent Transportation Systems (ITS) in many developed and developing countries is one of the many elements in that context. Following the same, Pakistan has undertaken several Initiatives to implement ITS along its major highways. However, all those projects faced major hindrances during their lifecycle; hence, no favorable results could be achieved. This research, therefore, will study the impact of prudent barrier factors that are the root cause for hindering the Effectiveness & Development of ITS-based atomized transportation management Projects in Pakistan.

2. Literature review

2.1.Intelligence Transportation System

Whereas, it is well said by Stephen Hawking that "Intelligence is the ability to adapt to change," to justify the adaptation, one always needs insight into the usage and application of a particular technological interface. The unanticipated growth of mobility has over-flooded significant cities with commuters/vehicles, which has uplifted the fatalities. The occurrence of emergencies, traffic congestions, inordinate delays, and fatal accidents have become an everyday myth which thus has revealed fundamental inefficiencies related to the transportation sector, and the development of safer and more efficient mobility has aroused the dire need for time. Also, the "World Health Organization (WHO); report" showed that accidents are the prime cause of death (Mathew & Bombay, 2014). A pursuant way to cope with the issue is to implement the recent findings in the field of communication to transportation management not only to lessen the fatalities but also to strengthen the economy, as the Road transport industry is considered vital for a flourishing economy and plays a crucial role in nations economic sustainability & development. Qureshi and Abdullah (2013) established that ITS plays a pivotal role in enhancing reliability, increasing travel safety, speed, and traffic flow while reducing the risk of accidents and minimizing carbon emissions, air pollution, and traffic congestion. Another prudent reason is the rapid urbanization that has resulted in several issues, from addressing congestion to freeways.

2.2.Intelligence Transportation System Concept

The intelligent transportation system, as defined by (McGregor, 2003), is.

"*a system of integrated communication, information, control, sensing, and system interoperation technologies primarily in terms of infrastructure, vehicles, and commuters to increase mobility by ensuring safety, real-time precise information decimation and economical transportation*."

Or,

"*Smart, Efficient, Safe management of freight and Economical and Informed commutation of commuters on the state highways*."

Thus, it can be noted that ITS is a product to attain high compatibility, having joined developed tools aimed to serve; "improved and extensive" metropolitan commutation and ensure safe, comfortable, and convenient movement for both commuters and inhabitants.

2.3. ITS Benefits and Technological Adaptation

ITS has a wide range of solutions developed primarily to cope with the number of daily faced transportation problems while addressing four distinct areas, namely: RealTime Navigation and Advanced Traveler Information, Commercial Vehicle Operations, Intelligent Automated Vehicles, and Advanced rural Transportation system to increase safety efficiency, productivity, and mobility (Giannoutakis & Li, 2012). While the abovementioned aspects are justified and acknowledged, it is not a cup of tea to stand with the race of the Globe. ITS is considered as "expensive or even exorbitant" in terms of infrastructure development and implementation, so it should be divided into several phases, with a well-versed plan able to integrate all the modules.

The most prudent benefits and significance of ITS, as categorized by (Vanderschuren, 2006), are Safety, Mobility, Efficiency, Productivity, Energy, and Environment, all of which can easily be met by a wide range of ITS technological adaptations as categorized by (Shaaban, Shamim, & Abdur-Rouf, 2021) including primarily; Traffic Operation Center (TOC), Closed Circuit Television (CCTV) Cameras, Variable/Dynamic Message Signs (VMS), Lane Control &Variable Speed Limit Signs (LCS & VSL), Weigh in Motion (SSWIM & HSWIM), Over height Vehicle Detection System (OVDS), Automatic Incident Detection system (AID), Automatic Vehicle Classifier System (AVC), Roadside Weather

Information system (RWIS), Emergency Roadside Communication system (ERT) and Tunnel Management & Safety systems.

2.4. Intelligent Transportation System Applications

Following the shift of regime in the latest era of transportation, Nations are more into adapting management techniques to manage the traffic intelligently instead of constructing increased highways. Pakistan also has an immense network of highways and motorways comprising 15000 km long, with millions of daily Commuters and costly installed assets all along the alignment. However, these immense networks of highways are proving insufficient with the ever-passing day due to the ever-increasing number of vehicles; the only viable way to cater is the adaptation of ITS instead of investing in constructing new highways parallel to the existing ones. The enormous advancements in the transportation field have enlightened the usage of ITS in enormous ways as modified accordingly by (ERTICO) European Road Transport Telemetries, Implementation and Coordination Org Vanderschuren (2006) and now as per latest amendment by Mathew and Bombay (2014) the practical application of advance ITS modules is tabulated hereunder.

All the ITS modules are currently being applied along the alignment and on significant bridges, Inside and the suburbs of tunnels, Toll Plaza, Weigh in Motion (WIMS), Service Areas, Trauma Centers, and Intersections. The working catalog of the installations made at all the locations mentioned above depends primarily on their assigned functions; for instance, the surveillance system installed at the tunnels and main crossings sections is different in functioning to those installed at the ramps and service areas. Similarly, the emergency telephone system inside the tunnels differs from the main carriageways. Although the system's basic application remains the same, the functionality depends upon the design and employers' requirements. The latest development in the field of ITS, as penned down by (Mathew & Bombay, 2014), endorsing the practical application of advanced ITS modules, is tabulated hereunder.

2.5. Tertiary

To identify the key constraints in the E&D of ITS projects, a systematic study based on the tertiary literature review approach, as recommended by Kitchenham, 2004 was carried out. To implement the strategy, the study's keywords were decided to keep in view the individual keyword relevancy, search volume, and user intent. The keywords hence selected were Intelligent Transportation System, Mobile transport, green mobility, technical

infrastructure, smart mobility, Barrier factors, IoT, wireless network, smart city, ICT, and Project risks. Following the keywords and using the methodology highlighted by Kitchenham,2004 the systematic study was conducted on 105 selected articles. After scrutiny based on keywords and parameters narrowed down to twenty and the barrier factors as identified.

The conceptual framework depicting all the hypotheses is shown in Figure 1.

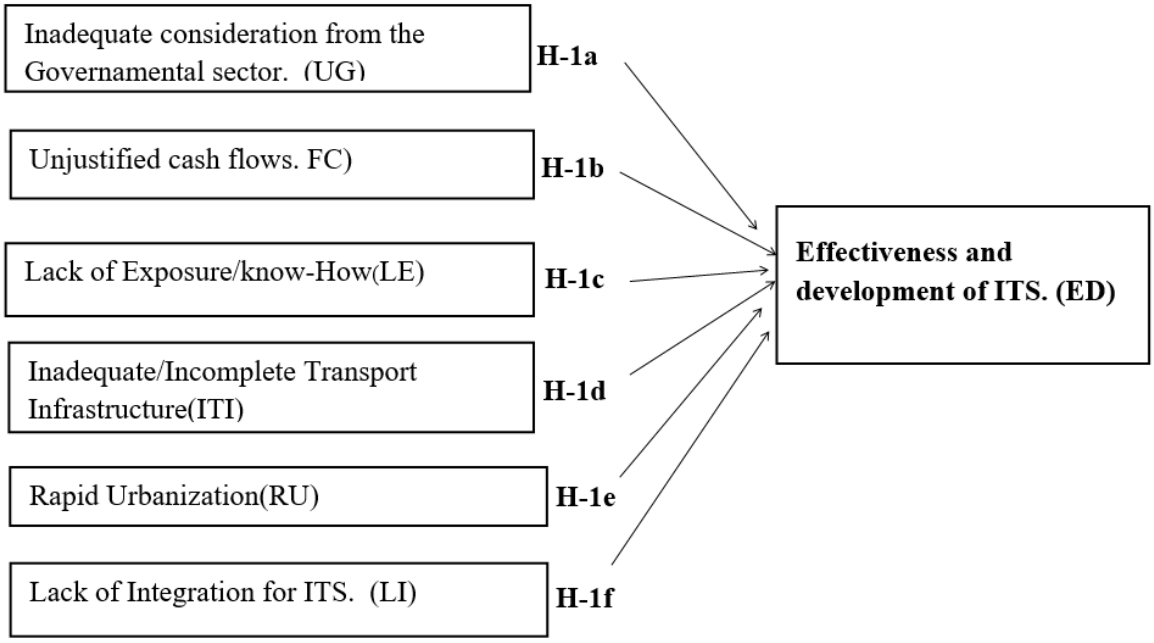

Figure 1: Conceptual framework

3. Methodology

3.1.Research Methodology

Research in the transportation sector has existed for ages, and every new regime concept is an everyday myth. However, due to a limited number of ITS projects implemented across the continent generally and in Pakistan pa, the mixed research methodology comprising qualitative and quantitative methods will be used. To identify the key constraints in the Effectiveness of ITS as well as the Development of ITS projects, a very systematic study will therefore be carried; out based on the tertiary approach of reviewing literature as recommended by researcher Kitchenham in 2004 by following the given steps; First, all the academic databases that are stored in the papers and then the e-book formats of worldly recognized journals will be explored by focusing on particular keywords joined up by expert opinions from some of successful ITS project managers. Thus, the database gathered from academia, and Focused group interviews will be tossed into a Questionnaire which will be

shared with different organizations/stakeholders who have prior interaction and are directly involved in the ITS Projects implementation. The crone-Batch Alpha technique will be used to test the liability of the Questionnaire. The response thus received by the Questionnaire will be assessed with the help of the Partial Least Square (PLS) Method of Structural Equation Modeling (SEM) by adequately testing the research Hypothesis. The multi-dimensional perspective of interrelated variables will thus be examined. The data will be analyzed using SPSS for descriptive analysis and SEM technique to test the hypothesis to check the interrelation among variables and their impact on the E&D of ITS.

3.2.Data collection

The data collection to carry out the research was a comprehensive phase composed of the following phases.

3.2.1. Tertiary Literature Review

To identify the critical constraints in ITS projects in terms of effectiveness and development, a systematic study based on the tertiary literature review approach, as recommended by researcher Kitchenham, 2004 was carried out. To implement the strategy, the study's keywords were decided to keep in view the individual keyword relevancy, search volume, and user intent. The keywords hence selected were Intelligent Transportation System, Mobile transport, green mobility, technical infrastructure, smart mobility, Barrier factors, smart city, wireless network, IoT, ICT, and Project risks. Based on the keywords, the academic databases together with the paper also formats of e-books inclusive of journals, conference papers, magazines, and American Society of Civil Engineers (ASCE) reports, Project Management Institute (PMI), Springer, IEEE, and Transportation journals, etc. were explored, and a total of 105 articles were selected. The articles shortlisted were further analyzed based on the following parameters.

- The articles must be in the English language.
- Articles must be from developed or developing countries.
- Must be related to the transportation sector; tunnels, bridges, subway, and elevated road types where ITS installations were in sighted.
- The Articles must speculate different techniques of calculating data from data collection.
- Should duplicate the method of content and implementation.

Following the abovementioned parameters, twenty research articles were selected for further analysis. The articles hence finalized for further scrutiny identified thirty-one factors that were repeatedly highlighted in the articles.

3.2.2. Focused Group Interviews

To verify the validity of the factors identified in the tertiary literature review, a focus group interview (FG) was conducted with ITS experts, Transporters, Contractors, and Designers (n=33) to identify the factors for study. An FG is the most preferable module for in-sighting end-user behaviors. Jamil et al. (2023) used FG to allocate the study factors, believing it the most practicable and trusted fact to select stimuli. A similar method was used in the under-subject study to validate the factors and gain preliminary insights into transporters' behavior and experimental stimuli (factors) selection. As a result, the FG members initially validated the proposed factors, which the study participants have authenticated. However, they were not part of the study later.

Upon asking the FG participants about the measures needed to ensure effective ITS development in Pakistan. Most believed foremost is the government involvement and investment in the latest transportation technologies (mode = 22), apart from many others. The members added that since the transportation sector is the backbone of a country's economy, the officials should deal with them. Therefore, following these recommendations, factors in alliance with the governmental umbrella were selected as a within-subject experimental stimulus for the present study. Participants stated that print, the wealthiest and most accessible source of expression, should be used for data collection (mode = 27). Hence the Questionnaire based on validation from tertiary literature review and FG was chosen for data collection, making it the final question asked. They were asked what the average length of the Questionnaire should be for collection.

In response, (mode = 22) stated its length to be between 02 and 04 pages, with personal demographics at the end. This follow-up has resulted in enough leisure without making them unwilling or bored.

3.3. Survey Questionnaire Design

An organized format for acquiring data via sample is a Questionnaire survey (Mazhar et al, 2023). It is a matter of common observation that this surveying mode is practical and concrete. Apart from the abovementioned fact, it is also believed to be a solution for performing quantitative data analysis from collection to results. Also, with this study,

participants are helped in acquiring background perceptions about the subject matter and can also easily carry out detailed analysis (Creswell, 2014). However, it will be prudent to mention that this research study is backed with biases and declined response trends; however, it is sometimes the most practicable technique in acquiring and analyzing massive data clusters. Hence, the Tertiary literature review data, joined with the Focus group opinion, was tossed in a questionnaire. The primary data from experts such as state officials and employees, architects, and engineers were then collected using that Questionnaire. These experts were related to construction in ITS Projects Contracting, Consultancy, experienced individuals, and professionals.

3.4.1 Structure of Questionnaire.

The Questionnaire comprised majorly of 05 central portions. The first section of the Questionnaire was composed of research aims and objectives as well as contact details of the respondent. The second portion comprises demographics, including experience on hand, designation, organization type, and work area. The rest portion contained the foundational part, using a Lickert scale (from not critical to most critical and not necessary to most important, equivalent to 1 to 5, respectively) to ask the respondents the importance of Intelligent transportation system (ITS). The fourth section, however, was designed, as argued by Lam et al. (2009) and Shi et al. (2013), which is necessary to assess the influence of potential factors affecting ITS effectiveness and development using SEM-PLS.

3.4.2 Reliability of Questionnaire.

Cronbach's alpha method is crucial for figuring out or determining the reliability of scales. The aim is to ascertain the overall dependency or internal consistency of factors within a survey questionnaire to pen down the Questionnaire's reliability. With its value ranging from 0 to 1, the technique helps determine the reliability of the diverse and dispersed scales. The higher the Cronbach's alpha coefficient value, the adopted measurement scale is more reliable. To determine the scale's reliability, Cronbach's alpha coefficient value should not decline from 0.70 (Nunnally, 1978). Using SPSS, the Cronbach's alpha coefficient value could be computed by (Li, 2003):

$$\alpha = \frac{k\overline{cov}/\overline{var}\mathbf{i}}{\mathbf{1} + (k-\mathbf{1})/\overline{var}\mathbf{i}}$$

However, the factors having standardization of norm and uniqueness in values, the formula gets adapted as follows:

$$\alpha = \frac{kr}{1 + (k-1)}$$

The scale applied to the study had a module for determining the five-point rating for the responses received using the Questionnaire. The results and outcomes obtained from the application are presented and interpreted in later sections.

3.4. Population and Sampling

This study employed an experimental design residing on internet users who participated. The study was marketed on social media platforms, email, and word of mouth to inform and attract the subjects. The participants who volunteered for the study followed the link to the survey page. A total of 270 respondents reached out to volunteer their opinions, of which 238 valid and authentic responses were retained for further analysis, representing a more than 89% respondent rate.

Two Sampling techniques used non-probability (snowball) for the referred-based construction field participants accumulating a total of (30%). In contrast, probability sampling (multi-stage) was explicitly allocated to experts from the ITS industry.

3.5. Modeling: PLS-SEM Method

Using the structural equation modeling (SEM) module, the research investigates the effect of different ITS adoption barriers, drivers, and promotion ways. SEM primarily comprises two types of variables.

- Observable variables (Measurement items; that can be measured directly).
- Latent variables (Constructs; that are liable to be measured directly and are desired to incorporate using third-party items.)

As penned down by Byrne, the SEM investigates the validity of hypotheses according to the determinants and applies a validating module to establish a structural hypothetical model based on a mechanism. That is, SEM evaluates; direct and indirect relationships among one or several independent variables. Since SEM goes beyond conventional multiple regression, ANOVA, and factor analysis (Qayyum et al, 2023), it was selected for analysis. Besides, from regression & factor analysis, SEM can ascertain confirmatory factor analysis (CFA) and path analysis; simultaneously in a single, structural equation model (Jamil et al., 2023). A typical structural equation model contains a set of measurement and structural models. A

measurement model establishes the relationships between a construct, and the measurement items, in the construct domain, whereas a structural model displays; the relationships among constructs (Hair et al., 2014a). SEM has been used in this study for barriers modeling, driver modeling, and as promoting strategies modeler. There exist two critical ways to SEM.

- The covariance-based SEM (CB-SEM) approach.
- Variance-based PLS-SEM approach.

It would be prudent to mention that PLS-SEM can handle small sample sizes and non-normal data, unlike CB-SEM (Joe F Hair, Sarstedt, Ringle, & Mena, 2012). This PLS-SEM advantage has given it an uprise in modern practice. Having a sample size of thirty-five professionals, Zhao and Singhaputtangkul (2016) used it to establish the impacts of firm characteristics; however, similarly, Aibinuet al. (2011) used PLS-SEM; to investigate the relationship between cooperative behavior and organizational justice, in construction, with a sample of forty-one contractors. Therefore, the present study adopted PLS-SEM, using Smart PLS 3.2.7 software, to assess the study hypotheses and validate the hypothetical models. The research hypotheses and models are developed and presented in the next chapter based on the EFA results.

CFA can measure relationships among items and their construct (Jamil & Qayyum, 2023). According to Joe F Hair Jr, Sarstedt, Hopkins, and Kuppelwieser (2014), the reliability and validity of the measurement items can also be established quickly within the measurement model after specifying the measurement and structural models. Evaluating the measurement models is vital: it helps to ensure; that the constructs, which form the basis for evaluation of relationships in hypothesized structural models, are represented, and measured accurately, hence, verifying the adequacy of the measurement models; for the path analysis. Reliability refers to the extent to which the measurement of constructs with a multi-item scale reflects; the accurate scores of the constructs relative to the error (Hair et al., 2019). However, the Composite reliability score and Cronbach's coefficient values are used to assess the internal consistency reliability of the items representing and measuring each construct. However, composite reliability scores are deemed to rise above 0.70 (Hair et al., 2019), and Cronbach's alpha coefficient is preferably above 0.70 (Nunnally, 1978). Once reliability is met, the validity: covering the convergent discriminate validity of the constructs, is next in the order.

Factor loadings picture the bi-variate correlations between measurement items and their corresponding construct, thus becoming the means of linkage (Hair et al., 2014a). For a satisfactory level, of convergent validity, each measurement item needs to have a factor

loading of 0.50 or higher (Hair et al., 2019), and the average variance extracted (AVE) of each construct; should also be 0.50 or higher (Fornell & Larcker, 1981). AVE is the grand mean value of the squared loadings of a set of measurement items and is equivalent to a construct's commonality (Hair et al. 2014a, b). Discriminant validity tests whether a construct measures what it originally intended to measure; simply put, discriminant validity evaluates the extent to which a construct differs from other constructs. The critical *t*-values for a two-tailed test were 1.65(significance level = 10%), 1.96 (significance level = 5%), and 2.58 (significance level = 1%) (Joe F Hair Jr et al., 2014). A detailed analysis based on standards for SEM-PLS is presented in the next section.

4. RESULTS AND DISCUSSION

4.1.Measurement Model Assessment

The measurement model assessment will be further divided into outer and internal parts. (Hair et al., 2019) Argued that applying the PLS-SEM technique makes it binding to establish the outer & inner SEM models.

4.2.Convergent Validity

Convergent validity is a measurement tool used in the initial step to eliminate indicators, and it adheres with the remaining trials of the same construct. The significant outer loadings indicate linkage and figuring out that associated indicators work on the construct, which is similar and considered indicator reliability. As per the studies by Hair et al., 2019, if outer loading surpasses numerically 0.70, then the indicator is accepted; however, anything lying between 0.40 and 0.70 in number is an indicator for the reconsideration and annulment of the construct. Similarly, the variable is ensured for exemption and stands out convergent validity if bears and depicts below 0.70, hence eliminated in this study. The other element of prime consideration taken on board in the company of outer loading assessment is the average variance extracted (AVE). It is considered a "rule of thumb" method for creating an AVE rating threshold. It noted that when AVE bears anything surplus to 0.50, the construct explains the variation above 50%, and the model can become accurate in convergence. Table 4.1 illustrates values for outer loadings for each of the constructs.

Construct	AG	FC	ITI	LE	LI	RU	UG
AG1	0.827						

AG2	0.856				
AG3	0.809				
AG4	0.624				
AG5	0.811				
AG6	0.705				
AG7	0.79				
AG8	0.768				
AG9	0.626				
FC1		0.857			
FC2		0.885			
FC3		0.846			
ITI1			0.757		
ITI2			0.87		
ITI3			0.821		
ITI4			0.615		
ITI5			0.83		
LE1				0.756	
LE2				0.757	
LE3				0.766	
LI1					0.756
LI2					0.731
LI3					0.723

LI4	0.703	
LI5	0.816	
LI6	0.725	
RU1		0.829
RU2		0.78
RU3		0.771
RU4		0.655

Table 4.1 **Convergent validity**

Based on the abovementioned conditions, the analysis result/values of AG_F9, ITI_F4, and RU_F4 indicators will be omitted as the outer loading value is below 0.70. As in the first step of the analysis of the measurement model (outer), the path model is re-defined using twenty-seven indicators with SIX variables being exogenous latent (AG, FC, ITI, LE, LI, RU) along with Fifteen indicators with variables that are endogenous latent (ED). After analysis, the model shown in Figure 4.1 would constitute the study base. Table 4.2 indicates that the value of the AVE of every element range from 0.647 to 0.744. All indicators surpass 0.50, making them convergent validate.

Factor	**Average Variance Extracted (AVE)**
E & D	0.647
FC	0.744
ITI	0.682
LE	0.739
LI	0.655

RU	0.738
UG	0.692

Table 4.2 **Avg. Variance Extracted**

4.3.Internal Consistency Reliability.

The internal consistency reliability measures present internal consistency based on intercorrelations of the observed variables. Based on the research study of various Research, the acceptable reliability of variables is measured based on Cronbach's Alpha value of 0.70. However, As per Kim & Peterson's finding, Cronbach's Alpha coefficient is not an accurate way to know the reliability of the Questionnaire; hence, another method is the result from composite reliability (CR), making it as closer to the reliability value ranging 0-1, the value closer to 1 is considered to be more reliable. The value of CR ranges between 0.70- 0.95, representing satisfactory-to-good reliability. The following Table 4.2 illustrate the Cronbach's Alpha results of the items, which ranged from 0.854-0.899, while the CR results ensured the place ranges between 0.901- 0.922. The value of Cronbach's Alpha and CR values are in surplus to 0.7 and <0.95; therefore, the internal consistency and reliability indicators are at par with the reliability conditions of the Questionnaire.

The study employed multiple parameters to assess the measurement model. Joseph F Hair, Risher, Sarstedt, and Ringle (2019) suggested testing internal consistency through Cronbach's alpha, convergent validity (composite reliability, average variance extracted), and discriminant validity.

Cronbach's alpha evaluated the internal consistency reliability of the measuring items, and all variables were higher than 0.70. Convergent validity is assessed through composite reliability and average variance extracted. The composite reliability (CR) ranges from 0 to 1, with acceptable values over 0.70 (Graciola, De Toni, Milan, & Eberle, 2020). Since CR values for all the constructs range from 0.87 to 0.96, therefore, considered satisfactory. The average variance extracted should be higher than 0.5 (Joseph F Hair Jr, Hult, Ringle, & Sarstedt, 2021). The observed AVE values ranged from 0.59 to 0.74, hence acceptable. Collectively, CR and AVE verified the convergent validity of measures. Table 4.3

summarizes the measurement model assessment based on Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE).

Factor	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
E & D	0.961	0.963	0.965	0.647
FC	0.879	0.838	0.897	0.744
ITI	0.883	0.885	0.914	0.682
LE	0.874	0.827	0.895	0.739
LI	0.894	0.895	0.919	0.655
RU	0.883	0.896	0.918	0.738
UG	0.913	0.919	0.928	0.592

Table 4.3 Internal Reliability.

4.4. Discriminant Validity.

To examine the remaining variables of the same model, discriminant validity (DV) is used. The DV establishes the uniqueness among the other items in a measurement model. According to the traditional approach, to measure the correctness in discrimination is suggested by Fornell and Larcker (1981), the method utilization of square root of AVE, while Henseler et al. (2015) suggested another modern approach known as heterotrait – monotrait (HTMT). The results of the HTMT, if they are in surplus to 0.90, illustrate items lacking the DV; however, in the practical studies, the results, if they bear any number lower to 0.85, are desirable and are accepted as distinct. Considering the same, Table 4.4 presents the square root of AVE values in higher order than their respective e latent variables.

The discriminant validity refers to an empirically distinct construct from the cluster. As a general practice in work, the AVE of each item should be compared; to the squared inter-construct correlation of that item and all other reflectively assessed constructs in the structural model (Fornell & Larcker, 1981).

In addition to the AVE approach, Joseph F Hair et al. (2019) suggested using the heterotrait-monotrait (HTMT) ratio of correlations to assess discriminant validity. It requires computing bootstrapping confidence intervals with five thousand resamples. The HTMT is a more trustworthy approach for assessing discriminant validity (Joseph F Hair Jr et al., 2021). The threshold value is 0.90 for conceptually similar constructs, while for conceptually distant constructs, bearing a lower numerical figure than 0.85 is considered acceptable (Henseler, Ringle, & Sarstedt, 2016). At the same time, others believed that any value less than 1.00 was acceptable. In either case, all the observed HTMT values are below the given limits, indicating adequate discriminant validity. The values in Table 4.4 show the test for discriminant validity based on HTMT ratios.

Construct	E&D	FC	ITI	LE	LI	RU
UG	0.816					
FC	0.874	0.959				
ITI	0.807	0.792	0.933			
LE	0.799	0.886	0.888	0.89		
LI	0.817	0.79	0.802	0.833	0.853	
RU	0.84	0.898	0.861	0.812	0.868	0.811

Table 4.4 Discriminant Validity

4.5.Relationships Significance and Evaluation of Relevance.

This is established as a structural model relationship when exogenous latent variables bear footprints on endogenous latent variables regardless of direct and indirect effects. Following the boot-strapping method, the standardized beta coefficient was analyzed, and hypotheses were assessed. The results were found to be significant except for the one for inadequate or incomplete transportation infrastructure, as evident from the P-values accordingly. Further, the hypothesis is rejected when the beta coefficient is different from zero, which is not the case here; hence, it shows a significant relationship and authenticates the variables and results as significant.

	Beta	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
FC -> E & D	-0.219	0.082	2.665	0.008
ITI -> E & D	-0.221	0.142	1.558	0.12
LE -> E & D	-0.256	0.109	2.349	0.019
LI -> E & D	-0.41	0.127	3.223	0.001
RU -> E & D	-0.242	0.1	2.427	0.016
UG -> E & D	-0.367	0.135	2.715	0.007

Table 4.7 **Structure Model Relationship.**

5. Discussion

Using PLS-SEM, the influence of barriers on the E&D of ITS projects within the demography of Pakistan has been established in this study. One of the foremost priorities is the Path model establishment for study. Evaluation of all standardized beta coefficients in SEM results in research pens out that all the factors have a significant impact on the effectiveness and development of the ITS in Pakistan, which is evident in R^2 value of 0.713 (71%), i-e, an excellent representation of the relevant factors however, it will be worth to mention here that there are still other factors which reserve key role and yet needed to be explored as a future research context. The results also prove the factors considered as the significant barrier/contributors towards E&D of ITS projects as the modeling of structural impact depicts that up to 70% of ITS effectiveness and ITS development is dependent upon undue attention of legislatures, impartial transport infrastructure, Financial incapability, the drastic up-rise of population, null exposure, and the unjustified exposure. However, 30% are linked to other elements.

The research has highlighted all the critical sub-areas (31 in total) contributing to the significant factors (06 in No) tabulated for the research. The corresponding values of the factor loading in all the cases are presented in Table 5.1 as well. The study also showed that the Lack of Integration (LI) of conventional transportation practices with the modern

technological infrastructure has resulted as a primary cause for hindering the effectiveness and development of ITS projects and has a significant negative impact on the E&D of ITS projects in Pakistan (beta = -0.410) at P = 0.0001 and T = 3.223, making it a significant predictor of ITS Effectiveness and Development (E&D). Also, Q^2 value helped determine the model's reliability, which was 0.416thus establishing a moderate prediction and assumed relevance as Q_2 value is greater than zero.

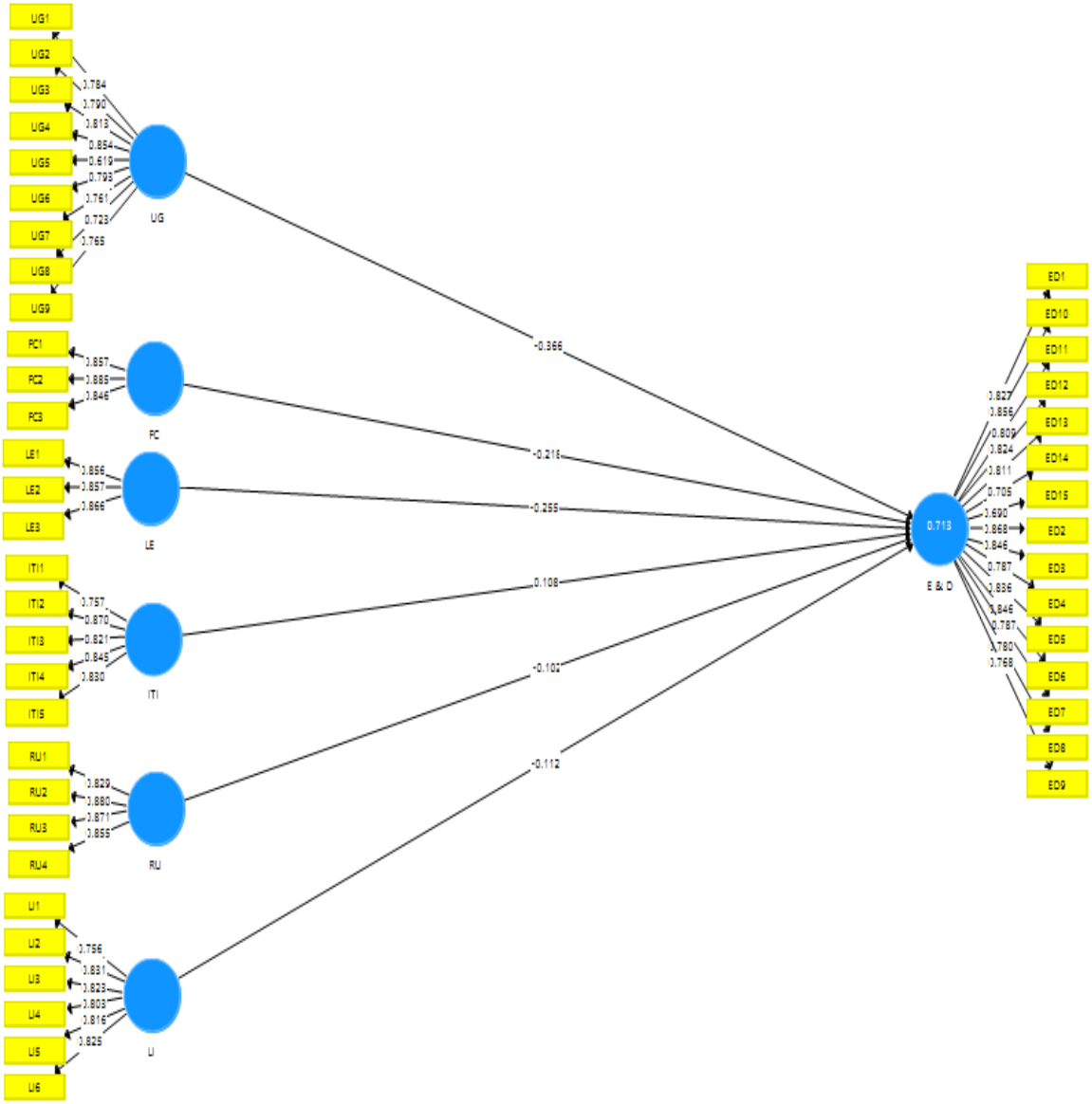

Figure 2: SEM

Like all others, the lack of Integration (LI) having (beta = 0.41) was measured by incorporating a comprehensive approach from stakeholders to customization and from application to scope. The results encompassed that the differences in the fundamental understandings regarding ITS among the stakeholders (beta= 0.756) resulted in differences of opinion among the policymakers and other internal & external stakeholders, thus, creating a gap in the effective integration right from the planning phase of the ITS projects. Further, this gap results in the simultaneous induction of the old and new methods (beta = 0.831), intensifying the gap and producing poor ITS customization (beta = 0.803). Further, the information insufficiency regarding planned and existing ITS modules (beta = 0.813) paves the way for the unrealistic skepticism of the ITS among the masses (beta = 0.816).

The public, unaware of the system's enhanced productivity, fruitfulness, and efficiency, doubts its credibility and prefers to opt for the same conventional modules used for ages. For instance, the mechanism of fixing the violations, i.e., Challan /fine on highways, is yet the same for ages; not only cumbersome but also risky and has become outdated in the contemporary world. Additionally, the methods of conducting the weighing practices for transit vehicles at weighbridges are also fallacious, least costly, and do not require a technical workforce capable of undertaking demanding assignments; however, all these have immense adverse effects on the lifecycle of the road and related transport infrastructure. When replaced with the one ITS, the exact old weighing mechanism will add to the highway's lifecycle/ performance and provide considerable savings in the long term to the national exchequer.

The study further pointed out that the undue consideration of the Government beholds the allocation of follow-up elements devastatingly impacting the (E&D) of ITS projects in Pakistan. Bearing a considerable negative impact on the E&D of ITS with (beta = 0.367), the lack of proper government consideration has undoubtedly been serving as a stem to the tree of a hindrance. The results showed that the unclear legal structure of the institutions of the country had postulated a real challenge to the country in order to compete with the pace of the developing nations (beta= 0.784); the unclear hierarchy at the top tiers has resulted in the inappropriate policy design which alternatively is distorting the way towards technological adaptation.

The prime factors contributing to the subject under discussion are the diversified bureaucracy (b= 0.79) and the conservative attitude of the authorities (b= 0.813), which is evident from the reduction in active participation (beta = 0.854) and abuse of authority (b = 0.619). Apart from those mentioned above, the policy dilemma that the state has been facing

in its wider arena since its birth goes the same in technological adaptation. Resulting in an average (b= 0.777), the lack of policy inherence and consistency has proven to be among the few others hindering the E&D of ITS. Thus, the Government's willingness, concern, follow-up, and intentions serve as a key in paving the way for technological advancements in a country to raise the standard of living of people and improve the country's International standing as well.

Factors leading from financing issues (FC) for ITS are nonetheless a key player in the degraded ITS E&D. It is based on four sub-areas: the declined and unjustified willingness to advancement (b = 0.809) insights the driver's behavior as unwilling to the technological adaptation. Following the curse of economic decline, many outdated, ill-maintained, and old vehicles seen commuting on the state highways also have huge dependencies on them; thus, a step towards green mobility is never welcomed in such transportation sectors. Secondly, inadequate resources for O&M (b = 0.852) of state-of-the-art ITS system is like a farfetched dream. In sighting the current maintenance mechanism on the state highways, one can validate the legitimacy of the factor of how capable we are or can meet the need for maintenance and operations of state-of-the-art ITS systems.

Further, the massive spending for ITS installation (b = 0.858) and the heightened distortions in the implementation of an ITS project (b = 0.872) are other factors that are well-versed and pay towards the growing financial constraints to aid for the effectiveness and development of ITS projects as ITS does require a notable sum to be invested.

The inadequate transportation infrastructure is next on the list (beta= 0.311). The term is tossed up with underdeveloped transportation infrastructure (Beta = 0.757), i.e., as per the Ministry of Communications website data, about 30% of the country's villages and towns lack basic transportation systems. However, those with one do not have the standard to compete with the international markings. This factor is further aggravated by the changes in space arrangements (beta = 0.87), primarily a product of unplanned urbanization. People from the rural areas have shifted to the cities and towns to get facilitated with the fruits of technology yet have become a significant threat to the same primarily due to a lack of general unawareness (beta = 0.821) and unplanned settlements.

The lack of adequate infrastructure results in the lack of exposure to the masses, making them unresponsive toward development initiatives. The product is a resultant End-user who does not want to get changed at any cost (beta = 0.845). People seem happy in the same traditional modes of traveling, boarding, and lodgings instead of adapting to developed ones

and prefer to live, in a nutshell of, the same conventional life. They are less motivated toward growth, which is one of the core factors behind the ineffectiveness and underdevelopment of the ITS projects.

Another critical factor affecting the ITS projects most is the lack of technical exposure/know-how (beta= 0.256). The primary factor driving this is the pathetic educational practice in the country; the advanced technological practices in the contemporary world are nowhere bound to the curriculum. The lack of a primary curriculum (beta = 0.856) is forming a professionally incapable society primarily because of the unskilled young scholars. When the graduates join the practical fields, they do not have enough exposure and understanding of the advanced modern tools; thus, they are unwilling to undertake creative roles and are not interested in research either. This also leads to the disparity between the practical and theoretical grounds (beta = 0.857) and an age of high unemployment in the country. Although substantial infrastructure projects are ongoing in the country, unemployment is still high primarily because the industries are unwilling to take the graduates who do not have the required competencies. The situation intensifies further as no specific event, seminar, etc., is being organized, or the concerned quarters take no keen initiatives (beta = 0.866) to overcome the current malaise.

Finally, Rapid Urbanization is also among the prime driving factor and critical hindrances within itself the ITS projects; having a (beta =0.282), it shows that the rapid urbanization and the unplanned urban boom (beta = 0,829) has created a bridge among the peers. The irregular landfill and development of cities without any planning or strategy have made it hard for the development sector to acquire land necessary to install and conduct infrastructure projects. The haphazard increase in the city population (beta = 0.88) has aggravated the need for technologically equipped modern transportation infrastructure (beta = 0.871) to serve best the smooth, economical, efficient, and safe commutation of people and goods from one place to another. The unrealistic policies (beta =0.855) from the concerned quarters have added fuel to the fire as the norms of red-tapeism and undue favor by the officials have made it more complicated to kick-start the country's technological development.

Thus, to conclude, it will be prudent to mention here that all the abovementioned factors are legitimate and have served the purpose to the fullest on broader grounds.

6. Conclusion

The study aims to determine the effect of the barrier factors using the constructive approach of SEM-PLS in the case of the demography of Pakistan. Considering this approach,

the factors' undue effect on the E&D of ITS projects was undoubtedly determined. Path model establishment for research is of prime consideration. The assessment of all beta coefficients in SEM research indicates that all the factors significantly impact the effectiveness and development of the ITS in Pakistan, which is evident in the R^2 value of 0.713 (71%), i-e, an excellent representation of the relevant factors. However, it will be worth mentioning here that other factors still reserve a crucial role and need to be explored in a future research context.

The results also prove the factors considered as the significant barrier/contributors towards E&D of ITS projects as evident from structural modeling a junk of 70% is subjected to undue attention of govt. (UG), Inadequate development (ITI), Finance issues (FC), the Population boom (RU), Lack of exposure (LE), and the Lack of Integration for ITS (RI), while 30% are other elements. Thus, it can be concluded that, for a nation to ensure development at an organic pace, it is of utmost importance to link the conventional practices being followed with the advanced technological innovations.

Further, the results hence obtained validate the hypothesis of the study and show that all the hypothesis (H1 **a** to **f)** set forth during the preliminary stage stands out as validated and demonstrates a significant negative impact on the Effectiveness and Development of the ITS. Hence the critical hypothesis i-e H1 (Factors harm E&D of ITS in Pakistan) stands to be validated.

6.1. Recommendation

Following the results obtained by modeling the model with SEM-PLS; it will be prudent to mention here that the key factors in the technological adaptation in Pakistan are Governance, Policies, Lack of exposure, Infrastructure, Integration, Economics, and unplanned growth. Thus, all these needs consideration to pave the way for a technologically advanced and technically equipped prosperous Pakistan. Apart from this, the recommendations are also included.

- A national ITS general plan comprising nationwide ITS Architecture must follow from the planning to the on-ground installation and operationalization of technology.
- The relative standards for the ITS installation and commissioning, along with SOPs for operations, should be drafted keeping in view Pakistan's infrastructure/cultural demography.
- Policymakers are unable to depict the benefits of the ITS effectively. ITS not only brings economic plus by positively affecting people's culture and daily life by

adequately linking the existing and future infrastructure. Thus, they also are causing the devastating loss to the national exchequer. Policymakers should strive to be more transparent about the benefits of technological adaptations on the masses' social and personal lives.

- Workshops, Seminars, and training should be arranged for the graduates and regular users to boost the collective benefits.
- National ITS center (NTOC) should be developed as the foremost priority to ensure the in-house accumulation, process, and outsourcing of data to enhance the productivity and efficiency of the system.
- The time taking process of ITS project implementation decreased the hope of many investors, preventing them from investing as it is a tiresome process to build up from scratch.
- Lack of coordination among the involved stakeholders results in disputed policies backed by pragmatic approaches, thus making it undoubted for the masses to trust the mechanisms. This lack of reliability and transparency hinders the effectiveness and development of nationwide ITS-based infrastructure shifts.

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