Impact of Fog Computing on Indian Smart-Cities: An Empirical Study

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Research Article

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Abstract

The article introduces a two-stage Structural equation modelling- Artificial Neural Network (SEM-ANN) model for the Smart city creation through Fog Computing (FC) and Internet of Things (IoT) by identifying the critical success factors in Indian context. The research article introduces a new factor Fog Computing (FC). Internet of Things (IoT) is again sub-divided into three more factors as Internet of People (IoP), Internet of Services (IoS) and Internet of Energy (IoE) as the independent variables. 13 Smart cities and 379 respondents are involved for this study. The data analysis is done through Structural equation modelling (SEM) and artificial neural network (ANN) which measures both the linear and non-linear relationships respectively. From Structural Equation Modeling (SEM) output, it is identified that Internet of Things (IoT), Internet of People (IOP) and Internet of Services (IOS) have some significant positive effect on Fog Computing (FC). Internet of Energy (IOE) has the negative effect on Fog Computing (FC) which is the only exception in the study for future research direction in this area. The SEM accepted variables are considered as the input for the next layer of ANN analysis that identified IOT has the major effect on Fog Computing (FC). A comparison is also done on SEM and neural network results. The outcome of the study will help more number of Smart City (SC) creations and will fulfil the target of 100 Smart city creation by Government of India taking forward towards a sustainable development.

Introduction

Linking Internet of Things (IoT) with smart sensing objects is a current trend. The smart device can collect, monitor and control the data in real world to internet and communication technology. Smart signifies hardware, software, cloud, sensing devices coming together to communicate through the data with the real world. Sensor devices are inbuilt in IOT through wired or wireless networks using some addresses links of computer networks. It will be useful in important decision making by some analytics. The Internet of Things (IoT) is a smart connected device which can communicate with the objects with some IP addresses. It can be of smart lighting, smart logistics, smart healthcare management which can be something innovative with smart technologies (Nam and Pardo, 2011; Monica Mital et al., 2017). Smart cities are city of internet connected through data where objects can interact with each other without any human interference. The Smart cities in India are encouraged to adopt IOT through Technology Acceptance Model (TAM). As a policy of Smart city creation, Government of India has declared for 100 Smart cities creations (Chatterjee et al., 2018). There are a number of studies on IoT, but its impact and the success ratio are demonstrated very less where the user can accept it. In this regard Smart city creation can encourage more number of potential users of IoT technology. More number of IoT devices will increase the volume of data where the Big-data will come in role. The data analysis can be done faster and more accurate through big-data analytics. These data are transformed to meaningful information for any decision making ability. Fog computing can be used to reduce the amount of data sent to the cloud for processing (Williams, & Weerakkody, 2015; Rana, Dwivedi, Lal, Williams, & Clement, 2017; Kapoor et al., 2014a; Chauhan et al., 2016; Chatterjee et al., 2017).

According to Wojick (2016), the new technologies like IOT, Big data analytics and Industry 4.0 will help the managers to fulfil the industry needs. Although these current technologies have certain advantages, still security is a major concern in this area. Now, the time is to know what encourages people to go for Internet of Things and what will discourage them from using smart devices like smart phones (Li et al., 2016). Internet of things again is associated with people, services, energy and Fog-computing for the usage, implementation and storage of data (Lom et al., 2016).

Cloud computing has the property of virtualization that can store a big amount of data over the internet and can provide the same to the organizations and the users dynamically (Robert & Jr, 2002). Cloud IOT technology is evolved to big data analytics, and now the age is of Industry 4.0. Cloud IOT provides the required storage, networking and applications to support all the current technologies. The huge data can be minimized and stored in the fog. Fog computing can support Big-data in terms of storage and networking the smart devices (Muntone, 2013). Fog computing and IOT solutions can give required information to guide the healthcare sector (Rifkin, 2011). IOT is recently applied to medical services that increase efficiency to cure the patients' illness (Hermann, 2016). The combination of cloud computing and IOT along with Industry 4.0 can resolve a number of problems through smart monitoring and tracking devices. Cloud computing, Big-data analytics and IOT along with Industry 4.0 gained lots of attention due to their problem solving capacity without any human intervention (Raut et al., 2019; Vaibhav et al., 2019). The study is more towards identifying the factors related to the usage of IoT devices leading to the success of Smart city creation.

Research Questions & Objectives:

RQ1. Identify the critical success factors that influence smart-city?

RQ2. What is the influence of each factor on Fog-computing?

RO1. To identify the critical success factors for smart city creation.

RO2. To identify the relationship among the factors of IOT and Fog computing.

The research article is organised as follows. After introduction next section is literature review which includes IOT, smart city, fog computing, previous studies on Structural equation modelling and artificial neural network (SEM-ANN) and research gaps. Section 3 covers the research methodology, empirical results in Sect. 4 and conclusion part in Sect. 5 that includes the discussion, limitations and future directions of research.

Background Study

Internet of things (IoT) can be combined as internet for people to ease the work, internet for different services, internet for energy saving. And the entire data generated from it are stored in the Fog computing (Patel & Patel, 2016). So, it becomes the powerful network of physical things through the internet without any human interference.

Internet of Things (IoT)

The upcoming revolution in Internet is known as IOT (Internet of Things). It has become a multidisciplinary research area in so many Industry, healthcare and institute specific studies. With the inception of multiple smart devices and smart phones, the IOT sensor machines are developing efficiently based upon the needs in our day to day life. Because of IOT, the healthcare system would be called as a personalised system. According to Chan et al. (2012) much more efforts have been taken for research on 'smart wearable things'. Vaibhav et al. (2019) identified IOT can reduce the overall cost by enhanced sustainability along with cloud computing which is known as Cloud of Things (COT). Solima et al. (2016) stated that internet can control any sensing device. Li et al. (2011) identified a smart object is one that has physical existence, ability to communicate, unique identification, name and address with some computing abilities and can act on the reality. IOT concept consists of a communicating device along with some cloud application. The sensing device can be controlled remotely through the internet (Miorandi et al., 2012). Gartner studies say the IOT smart devices will reach billions units by 2017. Nam and Pardo (2011) discussed about the smart homes, smart computing systems, sensors, smart embedded devices. Chatterjee et al. (2018) integrated IOT with Artificial Intelligence (AI) for the proposed 100 smart-cities development in India.

Atzori et al. (2010) discussed about various features and the major issues associated with Internet of Things (IoT).

IoT offers device to device connectivity through some smart services known as Internet of Services (IoS). These services are provided through the sensors and smart-grids. Internet of People (IoP) can connect the people with the environment that identifies the real world and virtual world. Energy saving is a very important concept. The energy produced can be saved through remote monitoring and the actual demand of energy can be known from the data generated from IoT where Internet of Energy (IoE) comes into role (Holler et al., 2014; Huang et al., 2012).

Smart-City (SC)

Smart city and IOT are popular phenomenon to resolve the financial crisis. Smart city is not only a technical aspect; a lot of humanitarian points are also involved. Smart City brings together all the technologies to enable smart movement, smart economy, smart individuals, smart governance and smart living. It ensures the sustainability of the smart city improving the quality of life and safety of people with the latest technologies in six key areas of environment, economy, people, governance, living and mobility (Lom, 2016). A constant effort is given by the European Union (EU) for achieving the growth in its metropolitan city (Paskaleva, 2009). The revolution in cities to smart cities should be implicit through some sequence of procedures. Smart city is definitely an important topic as in last few years as majority of people are moving from villages to cities. To become attractive and competitive, a city requires so many techniques. It does not need an innovative pattern how the smart cities should be like, and requires how the businesses run together, people and the academic thinking among them. The cities should be reinvented as the people should not be considered as the users, they should be treated as the key

stakeholders. Technologies should be used as a dynamic enabler. Business should be considered as partners, which will be a real transformation. A smart product monitors the entire life cycle of call, manufacture and distribution to the endpoint (Lom et al., 2016).

Lim et al. (2018) classified the urban data for analysis in four reference models and the challenges associated with it. Jong et al. (2015) tried identifying the factors or criteria required for a city to be sustainable. A smart city can be termed as green, full of knowledge, intelligence, digital, low-carbon, information oriented, liveable and resilient.

Tachizawa et al. (2015) proposed a research model to identify the relationship among smart city, big-data and supply-chain. A smart city is associated with some aspects of smart environment, smart transport, smart governance, smart people, smart livelihood, and smart mobility.

Fog-Computing (FC)

Fog-computing can be used to build the smart city where the significant data can be directed to the upper level and the rest of the data can be utilised in the local edges. It is a distributed computing technique used to store enough amounts of data. Some applications of fog-computing are stored in smart devices and some are in cloud. Its aim is to improve efficiency by reducing the amount of data sent to cloud for processing and storage. This can also be done for security and privacy reason (Bar-Magen, 2013).

The distributed approach of fog computing gained the popularity because of IOT technology. IOT contains so much of information and can be separated out in the next level to increase the efficiency (United Nations, 2015). IOT and smart city both can be connected through fog computing.

Studies on SEM-ANN

Mobile learning adoption is analysed using the Structural equation modelling-Artificial neural network, SEM-ANN hybrid method. The study is having some flaws because of the two factors namely; social influence and personal innovativeness which TAM never identifies (Tan et al., 2014). Chong and Bai (2014) studied on the integrated method of SEM-ANN by collecting the data from 136 small and medium scale enterprises. One organization can provide good service quality if we consider the competitive advantage in return (Leong et al., 2015). The influence of airlines service quality may affect the customers' satisfaction for more profit. It can have a direct effect to the low cost airlines using the same SEM-ANN predictive model (Shmueli & Koppius, 2011). Khayer et al. (2019) studied on dual-stage analytic approach and the results were signified by importance-performance map. The impact of Cloud computing adoption on small and medium scale enterprises (SMEs) were identified in this study.

Hew et al. (2016) collected the data from 524 mobile phone handlers and studied upon the SEM-ANN hybrid model to extend TAM adding the factors like perceived financial cost. Yadav et al. (2016) adopted m-commerce technology to study artificial neural network using PLS tool. The data collection was done from 459 mobile users. Priyadarshinee et al. (2017) used a hybrid approach based on Structural equation modelling (SEM) and neural network (ANN) in their study for testing the similar kind of hybrid model.

Research Gaps

The articles discussed about Smart city, Big-data analytics, Cloud computing and Internet of Things (IoT) adoption in Industries. Some studies are Industry specific like SMEs and multiple case studies methods. Few studies carry certain research models and some are surveys on Smart city. Rarely the discussion of Fog Computing is done for building a Smart city which has the ability to minimize the data storage. There are certain variations between cloud computing and IOT, but rarely we connect this to Fog-computing which stores the intermediate data with energy efficient. The critical success factor identification for the success of smart-city is done in very specific studies. No study identifies effectiveness of variables on Smart city.

Table 1
Gaps Identified from the Studies

Sl.no.	Country and Industry	Model Used	Summary	References
1	German Manufacturing Industries	Interrelationship Model	A multiple case-study method was used for 76 manufacturing companies.	Kiel et al. (2017)
2	India, Smart Machines	IOT Framework	The study integrates AI (Artificial Intelligence) with IOT in terms of smart machines without any human intervention.	Chatterjee et al. (2018)
3	Indian SMEs	Structural Equation Modeling (SEM) with 5-point likert scale.	The paper introduced cloud computing and IOT as Cloud-IOT (COT) adoption in India. The study is focussed on 270 SMEs in India.	Vaibhav et al. (2019)
4	Korea	No research Model	The study explains how to analyse or transform big-data to information for building a smart-city.	Lim et al. (2018)
5	Australia and non-industry specific study	Aneka Cloud	It presents a cloud centric vision with the world-wide implementation of IOT.	Gubbi et al. (2013)
6	Poland, Library	Library Activities Model	It discusses about how IOT can be used in Libraries.	Magdalena Wójcik (2016)
7	Egypt, Healthcare sector	Cloud and IOT model using Genetic Algorithm	The study is intended to enhance the performance of healthcare sector by Cloud-IOT.	Elhoseny et al. (2018)
8	Canada, Smart community	Pervasive healthcare system	The article introduced about smart community with the help of IOT.	Li et al. (2011)
9	Italy, Smart city	No specific conceptual model	The paper emphasizes Internet of Things as knowledge sharing platform through networking	Solima et al. (2015)
10	Europe, Smart City IOT	Real-time Experimental Testbed	The study explains the experimental aspects of smart city and IOT from European Commission.	Sanchez et al. (2014)
11	Taiwan, Particulate matter (PM) for Smart city	CNN-LSTM (Convolution Neural Network – Long Short-Term Memory) Model	The article develops a CNN-LSTM model to reduce the air pollution for smart city creation.	Huang and Kuo (2018)
12	Spain, Smart city, Big-data and Supply networks	Integrative framework	The article tried identifying the relationship among smart-city, supply-chain and big-data analytics.	Tachizawa (2015)

Sl.no.	Country and Industry	Model Used	Summary	References
13	Korea, IOT & Smart city	Survey from 200 Experts	The article focuses on IOT technology for building a smart city.	Park et al. (2018)
14	Netherlands, Low carbon city	No specific research model	The paper discusses about various aspects of smart city; how it can be eco-friendly, low carbon, knowledgeable and sustainable.	DeJong et al. (2015)
15	Mexico, Sustainable environment & Smart city	No research Model	The study is mostly on sustainable Smart-city based on research models, & tools used in review.	Trindade et al. (2017)

Conceptual Model & Hypotheses Development

It is the inter-relationship between the endogenous and exogenous variables in a structured manner. Some kind of dependent and independent relationships are there among the factors.

At initial stage some logical grouping is done among the items to form the constructs. Data was collected from 13 Smart-cities out of 20 smart-cities in India for pilot study. After the pilot analysis, the final set of variables was identified. With the help of final variables, the research model and hypotheses were framed. A one-point to seven-point likert scale was used for data collection. The number of items was reduced after the pilot study. Five hypotheses were framed in the study.

The following hypotheses are formulated from the above conceptual framework.

H1: Internet of Things (IoT) affects Fog Computing (FC).

H2: Internet of Services (IoS) affects Fog Computing (FC).

H3: Internet of People (IoP) affects Fog Computing (FC).

H4: Internet of Energy (IoE) affects Fog Computing (FC).

H5: Fog Computing (FC) affects Smart City (SC).

Research Methodology

Sample characteristics

390 responses were received from 13 smart-cities in India out of which 379 responses were valid. Per city wise distribution was 15%-25% in each smart-city. 50 % of the respondents were male compared to female respondents. For 38 valid items in the questionnaire, as per 1:10 ratio, maximum 380 respondents can be taken (Hinkin, 1996). So, 379 responses were identified as valid responses through

factor analysis and considered finally for further study. More of the respondents were in the age group of 21 to 35. Male respondents were more compared to the female respondents. The undergraduate respondents were more than the post graduates. Mostly south India was the target geographical region for data collection which almost took five months.

Exploratory factor analysis

As per Hair et al. (2010) factor analysis helps in data reduction and identifies the structure among the variables and items. In factor analysis, majorly we check the KMO (Kaiser–Meyer–Olkin) value to know the accuracy of the data. The KMO value more than 0.65 is good for further analysis. For new scale development varimax technique is used. Rotated component matrix is taken into consideration for confirmatory factor analysis in next phase.

Confirmatory factor analysis

Confirmatory factor analysis determines the model fit along with the validity and reliability. Reliability is measured through composite reliability (CR) and validity is measured through discriminant validity by AVE (Average Variance Extracted). The CR values more than 0.7 is acceptable and AVE should be more than 0.5. The correlation among the factors is measured by the correlation matrix. For discriminant validity the square root of AVE must be larger than the correlation coefficients in the matrix (Malhotra, 2010 & Hair et al., 2010).

Structural Equation modelling

Structural equation modelling is a widely accepted technique for hypothesis testing. It is a better alternative as compared to multiple regressions. SEM can identify the error terms whereas regressions don't. There are two types of errors in SEM, one is residual error and another one is measurement error. The standardized regression weights measure the acceptance of each hypothesis. Squared multiple correlation identifies the weights of each residual error.

Empirical Result

In statistical analysis, EFA was performed using the IBM SPSS statistics V20, and for CFA and SEM, AMOS V22.0 was used. Structural equation modelling was used to test the hypotheses for model validation.

Exploratory Factor Analysis (EFA)

During Exploratory Factor Analysis, varimax was used to generate new scale in principal component analysis. The KMO value 0.933 was acceptable as it was greater than 0.65, the threshold value. The bartlett's test of sphericity was 0.00 below 0.05 which is acceptable at 95% confidence level. Rotated component matrix is shown in the following table. The values in the rotated component matrix more than 50% were taken into consideration as per the following table.

Confirmatory Factor Analysis (CFA)

Discriminant validity of individual variable was identified through square root of AVE that must be more than the correlation coefficients (Fornell and Larcker, 1981). The composite reliability and Cronbach's alpha of the factors crosses the threshold limit 0.7. All these Composite reliability (CR), Discriminant validity (AVE) and Cronbach's alpha are shown in the following table. Figure 2 signifies the path diagram for Confirmatory factor analysis.

Table 2: AVE, CR and Cronbach's Alpha Values

Sr. No.	Factors	AVE	CR	Cronbach's Alpha
1	Smart-City	0.592	0.726	0.925
2	Fog-Computing	0.553	0.774	0.960
3	Internet-of-Things	0.536	0.731	0.888
4	Internet of People	0.542	0.746	0.917
5	Internet of Energy	0.537	0.723	0.898
6	Internet of Services	0.591	0.704	0.913

Table 3: Correlation

Variables	SC	FC	IOS	IOP	IOE	IOT
SC	0.855					
FC	.114*	0.810				
IOS	.140**	.116*	0.722			
IOP	.392**	.105*	.342**	0.701		
IOE	-.092*	-.018	.016	-.032	0.811	
IOT	.024	.017	.047	.085	.029	0.832
*. Correlation is significant at the 0.05 level (2-tailed).						
**. Correlation is significant at the 0.01 level (2-tailed).						

Structural Equation Modeling:

The model fit is measured through the estimates of the model through regression co-efficient, goodness of fit index (GFI), adjusted goodness of fit index (AGFI), Comparative fit index (CFI) and root mean square error of approximation (RMSEA). Degrees of freedom (CMIN/DF) should be below 3.0, in our case it is

1.511 which is acceptable. The CFI value is 0.976 which should be more than 0.95. GFI is 0.907 which is more than the threshold value of 0.90. AGFI is 0.894 which is more than 0.85 threshold limit. RMSEA is 0.032 which is less than 0.05, hence acceptable (Hair et al., 2010). The following figure shows the SEM path diagram.

Hypothesis testing

The five hypotheses were tested using SEM in Amos 20.0. In this research model fog computing is the mediating variable, smart city is the dependent variable and the rest four variables are the independent ones. The analysis shows out of five hypotheses four were supported and one is not. The hypothesis which is not supported is the IOE that positively supports fog computing having -0.022 regression weight. Rest four hypotheses were supported as depicted in the following table.

Table 4: Hypotheses Testing

Hypothesis No.	Hypothesis	Significance	Results(Supported-Y/N)	In agreement with	In Contrast with
H1	Internet of Things positively influences Fog Computing.	.012	Yes	Mital et al. (2017)	-
H2	Internet of Service positively influences Fog Computing	.101	Yes	Lom et al. (2016)	-
H3	Internet of People positively influences Fog Computing	.083	Yes	Lom et al. (2016)	-
H4	Internet of Energy positively influences Fog Computing	-.022	No	-	Lom et al. (2016)
H5	Fog-computing positively influences Smart city.	.119	Yes	Lom et al. (2016)	-

ANN (Artificial Neural Network)

Artificial neural network (ANN) checks the non-linear relationship among the factors in a research model. Neural network analysis takes the study to the next level for testing the smart city as a dependent variable. It is a novel perspective of the study as neural network is applied for IOT, Fog computing and Smart city. The study is quite different from enterprise resource planning, e-commerce, e-mobile credit card system, cloud computing and big-data analytics. (Chong, 2013; Chong & Bai, 2014; Leong et al., 2013; Sim et al., 2014; Tan et al., 2014).

MLP (multi-layer perceptron) was used to check the hidden layer in the artificial neural network. The three layers (input, hidden and output layers) were shown in the above figure. A data partition was done for training and testing data in 90:10 ratios for tenfold cross validation in SPSS. The predicted variables significances were determined through the non-zero synaptic weights. The non-compensatory ANN analysis will be able to balance the drawbacks of compensatory SEM analysis. The two phase hybrid analysis technique of SEM-ANN is quite useful to determine the individual importance of each accepted independent variable (Priyadarshinee et al., 2017; Scott & Walczak, 2009; Shmueli & Koppius, 2011).

Table 5: RMSE Values

Artificial Neural Networks (ANN)	Fog-computing as output		Smart-city as output	
	Training	Testing	Training	Testing
A	.422	.111	.516	.721
B	.001	.523	.815	.777
C	.032	.324	.888	.231
D	.191	.132	.562	.439
E	.121	.149	.611	.532
F	.331	.288	.752	.566
G	.059	.452	.721	.951
H	.182	.321	.533	.821
I	.329	.425	.877	.629
J	.147	.122	.732	.837
<i>Mean RMSE</i>	<i>.1815</i>	<i>.2847</i>	<i>.7007</i>	<i>.6504</i>
<i>Standard Deviation</i>	<i>.132975</i>	<i>.143425</i>	<i>.131443</i>	<i>.204324</i>

Table 6: Sensitivity Analysis

Artificial Neural Network	IOT	IOP	IOS
1	0.097	0.281	0.311
2	0.199	0.019	0.324
3	0.311	0.2318	0.1129
4	0.256	0.341	0.1321
5	0.313	0.427	0.186
6	0.424	0.215	0.325
7	0.311	0.329	0.322
8	0.355	0.141	0.347
9	0.329	0.501	0.548
10	0.299	0.090	0.128
Mean Importance	0.2894	0.25758	0.2736
Normalized Importance (%)	100	89.00	94.54

Table 7: Comparison between SEM and ANN results

Factors	Standardized Weights in SEM	Ranking	Relative Importance on ANN	Ranking
IOT	0.012	3	0.2894	1
IOP	0.083	2	0.25758	3
IOS	0.101	1	0.2736	2

The comparison table of SEM and ANN shows in Amos SEM analysis, IOS is having higher value and IOT is having the lowest value. Whereas neural network result is more accurate and measures IOT is having the most important factor for Smart city creation.

Limitation

The model can incorporate some other technologies along with IOT. There might be structural holes in the network which might have some negative effect on the Smart city operations. As per Borgatti and Li (2009) when the structural holes are connected with some other supply-chain networks results in positive performance. The study is only applicable to Indian Smart cities. Same can be applied for other countries in other geographical locations. The research model is also only applicable to developing countries like India. It may vary for developed or under developed countries. Researches can find out till what extent IOT and Fog computing together influence the Smart city creation. Some other approaches could be used to

measure the weight of each factor which can be a hybrid methodology integrating SEM and ANP. With higher sample size in mixed methodology, the result might be different.

Conclusion

The present study identified six critical success factors that influence smart-city adoption. Structural equation modelling is used for analysis. The relationship between each factor is identified through exploratory factor analysis. Based upon the research questions, research objectives were framed for the study. It may be noted that smart-city is controlled by fog-computing that enables the objects in the smart-city. IOT is the major technology for the establishment of a smart city. It is clearly visible from the study that fog-computing affects smart-city majorly with higher value of regression weights of 0.119. IOT, IOS and IOP have significant effect on fog computing. The positive effect of IOT on fog computing also explained in the previous studies (Lom et al., 2016).

In our present study IOE negatively affects fog computing, it shows Internet of energy has negligible effect for building a smart-city. Real time implementation of smart-city is possible through fog-computing and IOT. The study is useful for all IOT enabled smart cities in India and will help the academicians to do further study.

Managerial Implications & Future Scope

Different methodology can be used to check the outcome of the study. The first managerial implication says IOT and Fog computing alone has less impact on Smart city initiatives, but combined these technologies can solve the wonder. Secondly, the integrative dual-stage model can tackle to the new business models. Thirdly, IOT will provide a mechanism to provide the data online for the customers in cloud, but it leads to the security issues as a new research agenda.

Comparative studies will be more helpful to get the correct output. It will help the managers to frame a smart city more accurately. The study will guide government agencies to frame policies for smart-city. The IOT service providers will work more effectively by showcasing the result output as their strong point.

Declarations

Conflict of interest: I declare that it is the sole work by me and there is no conflict of interest exist in my work.

Human and animal rights statement: Humans/animals are not involved in this work.

References

1. Numhauser B-M, Jonathan (August 25, 2013) *"XMPP Distributed Topology as a Potential Solution for Fog Computing"*. MESH 2013 The Sixth International Conference on Advances in Mesh Networks

2. Borgatti SP, Li X (2009) On Social Network Analysis in a Supply Chain Context. *Journal of Supply Chain Management* 45 No(2):5–22
3. Chatterjee S, Kar AK, Gupta MP (2018) Success of IoT in smart cities of India: An empirical analysis. *Government Information Quarterly* 35(3):349–361
4. Chong AYL (2013) A two-staged SEM-neural network approach for understanding and predicting the determinants of m-commerce adoption. *Expert Syst Appl* 40(4):1240–1247
5. Chong AYL, Bai R (2014) Predicting open IOS adoption in SMEs: An integrated SEM-neural network approach. *Expert Syst Appl* 41(1):221–229
6. De Jong M, Joss S, Schraven D, Zhan C, Weijnen M (2015) Sustainable–smart–resilient–low carbon–eco–knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization. *Journal of Cleaner production* 109:25–38
7. Elhoseny M, Abdelaziz A, Salama AS, Riad AM, Muhammad K, Sangaiah AK (2018) A hybrid model of internet of things and cloud computing to manage big data in health services applications. *Future generation computer systems* 86:1383–1394
8. Fornell C, Larcker DF (1981) Evaluating structural equation models with unobservable variables and measurement error. *J Mark Res* 18 No(1):39–50
9. Graham G, Tachizawa EM, Alvarez-Gil MJ, Montes-Sancho MJ (2015) How “smart cities” will change supply chain management. *Supply Chain Management: An International Journal*
10. Gubbi J, Buyya R, Marusic S, Palaniswami M (2013) Internet of Things (IoT): A vision, architectural elements, and future directions. *Future generation computer systems* 29(7):1645–1660
11. Hair JF, Anderson RE, Tatham RL, William CB (2010) *Multivariate Data Analysis*. Pearson Education, Essex
12. Hermann P, Otto (2015) *Design Principles for Industrie 4.0 Scenarios*, accessed on 3 February 2015
13. Hew TS, Leong LY, Ooi KB, Chong AYL (2016) Predicting Drivers of Mobile Entertainment Adoption: A Two-Stage SEM-Artificial-Neural-Network Analysis. *Journal of Computer Information Systems* 56(4):352–370
14. Hinkin IP (1996) A review of scale development in the study of behavior in organizations. *J Manag* 21(5):967–988
15. Höller J, Tsiatsis V, Mulligan C, Karnouskos S, Avesand S, Boyle D: *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*. Elsevier, 2014, ISBN 978-0-12-407684-6
16. Rifkin J, *The third industrial revolution: how lateral power is transforming energy, the economy and the world*. 1st ed. New York: Palgrave Macmillan, 2011, 291 s. ISBN 9780230115217
17. Paskaleva K (25 January 2009) “Enabling the smart city: The progress of e-city governance in Europe”. *International Journal of Innovation and Regional Development* 1(4): 405–422(18). doi: 10.1504/ijird.2009.022730
18. Khayer A, Talukder MS, Bao Y, Hossain MN (2020) Cloud computing adoption and its impact on SMEs’ performance for cloud supported operations: A dual-stage analytical approach. *Technol Soc*

19. Kiel D, Arnold C, Voigt KI (2017) The influence of the Industrial Internet of Things on business models of established manufacturing companies—A business level perspective. *Technovation* 68:4–19
20. Li S, Tryfonas T, Li H (2016) The internet of things: a security point of view. *Internet Res* 26(2):337–359
21. Li X, Lu R, Liang X, Shen X, Chen J, Lin X (2011) Smart community: an internet of things application. *IEEE Commun Mag* 49(11):68–75
22. Leong LY, Hew TS, Tan GWH, Ooi KB (2013) Predicting the determinants of the NFC-enabled mobile credit card acceptance: A neural networks approach. *Expert Syst Appl* 40(14):5604–5620
23. Leong LY, Hew TS, Lee VH, Ooi KB (2015) An SEM–artificial-neural-network analysis of the relationships between SERVPERF, customer satisfaction and loyalty among low-cost and full-service airline. *Expert Syst Appl* 42(19):6620–6634
24. Lim C, Kim KJ, Maglio PP (2018) Smart cities with big data: Reference models, challenges, and considerations. *Cities* 82:86–99
25. Lom M, Pribyl O, Zelinka T, “*System Engineering for Smart Cities*”, WMSCI 2016, Orlando
26. Malhotra NK (2010) *Marketing Research: an Applied Orientation*, 6th edn. Pearson Education India. Bengaluru
27. Miorandi D, Sicari S, De Pellegrini F, Chlamtac I (2012) Internet of things: vision, applications and research challenges. *Ad Hoc Netw* 10(7):1497–1516
28. Mital M, Chang V, Choudhary P, Papa A, Pani AK (2018) Adoption of Internet of Things in India: A test of competing models using a structured equation modeling approach. *Technol Forecast Soc Chang* 136:339–346
29. Nam T, Pardo TA (2011) Conceptualizing Smart City with dimensions of technology, people, and institutions. *Proceedings of the 12th Annual International Digital Government Research Conference on Digital Government Innovation in Challenging Times*, p. 282
30. Narwane VS, Raut RD, Gardas BB, Kavre MS, Narkhede BE (2019) Factors affecting the adoption of cloud of things. *Journal of Systems and Information Technology*
31. Narwane VS, Raut RD, Mangla SK, Gardas BB, Narkhede BE, Awasthi A, Priyadarshinee P (2020) Mediating role of cloud of things in improving performance of small and medium enterprises in the Indian context. *Annals of Operations Research*, 1–30
32. Park E, Del Pobil AP, Kwon SJ (2018) The role of Internet of Things (IoT) in smart cities: Technology roadmap-oriented approaches. *Sustainability* 10(5):1388
33. Patel K, Patel S (2016) Internet of things-IoT: Definition, characteristics, architecture, enabling technologies, Application & Future Challenges. *International Journal of Engineering Science Computing* 69(5):6122–6131
34. Priyadarshinee P, Raut RD, Jha MK, Gardas BB (2017) Understanding and predicting the determinants of cloud computing adoption: A two staged hybrid SEM-Neural networks approach. *Comput Hum*

35. Raut RD, Mangla SK, Narwane VS, Gardas BB, Priyadarshinee P, Narkhede BE (2019) Linking big data analytics and operational sustainability practices for sustainable business management. *Journal of cleaner production* 224:10–24
36. Robert E. Lucas, Jr (2002) *Lectures on Economic Growth*. Cambridge: Harvard University Press. pp. 109–10. ISBN 978-0-674-01601-9
37. Muntone S, "Second Industrial Revolution". *Education.com*. The McGraw-Hill Companies. Retrieved 14 October 2013
38. Sanchez, L., Muñoz, L., Galache, J. A., Sotres, P., Santana, J. R., Gutierrez, V.,... Pfisterer, D. (2014). SmartSantander: IoT experimentation over a smart city testbed. *Computer Networks*, 61, 217–238
39. Shmueli G, Koppius OR (2011) Predictive analytics in information systems research. *MIS Q* 35(3):553–572
40. Sim JJ, Tan GWH, Wong JCJ, Ooi KB, Hew TS (2014) Understanding and predicting the motivators of mobile music acceptance – a multi-stage MRA–artificial neural network approach. *Telematics Inform* 31(4):569–584
41. Solima L, Della Peruta MR, Del Giudice M (2016) Object-generated content and knowledge sharing: the forthcoming impact of the internet of things. *J Knowl Econ* 7(3):738–752
42. Tan GWH, Ooi KB, Leong LY, Lin B (2014) Predicting the drivers of behavioral intention to use mobile learning: A hybrid SEM-Neural Networks approach. *Comput Hum Behav* 36((1)):198–213
43. Trindade EP, Hinnig MPF, da Costa M, Marques E, Bastos JS, R. C., & Yigitcanlar T (2017) Sustainable development of smart cities: A systematic review of the literature. *Journal of Open Innovation: Technology Market Complexity* 3(3):11
44. United Nations, Department of Economic and Social Affairs, Population Division (2015) *World Population Prospects: The 2015 Revision, custom data acquired via website*
45. Buscher V, Doody L, Webb M, Ch. Aoun. *Smart Cities cornerstone series: Urban mobility in the Smart City age*. Arup
46. Wojick M (2016) Internet of things - potential for libraries. *Library Hi Tech* 34 (2)–420
47. Yadav R, Sharma SK, Tarhini A (2016) A multi-analytical approach to understand and predict the mobile commerce adoption. *Journal of Enterprise Information Management* 29(2):222–237
48. Werner Y-FH, Jing S, Kashyap H, Gupta N, V., "State Estimation in Electric Power Grids: Meeting New Challenges Presented by the Requirements of the Future Grid," *Signal Processing Magazine, IEEE*, vol.29, no.5, pp.33,43, Sept. 2012

Figures

Figure 1

Conceptual Framework

Figure 2

CFA Path Diagram

Figure 3

SEM Path Diagram