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Digitizing grey portions of e-governance

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Abstract

Purpose – The purpose of this research paper is to assess e-Governance efficacy in various sectors of India. The paper develops on GST methodology and enlightens grey portions of e-Governance in select sectors. Research study identifies few grey criteria which affect implementation of ICT applications to support sustainable e-Governance. Such criteria are related to information security breaches, IT policy implementation, investments and strategic advantages for the various sector developments.

Methodology – Considering 'information' as sensitive element to security for administration and part of dark portion to Indian economy, GST based COmplex PRroportional ASsessment (COPRAS-G) method is adopted to assess the e-Governance efficacy. The method provides flexible MCDM approach to assess e-Governance in prioritize the sector alternatives of future strategic development. Priority order of select sectors is estimated and COPRAS-G method is used in the research study to support decision making on e-Governance. Study compares ten major GDP dependent sectors based on few grey criteria. These criteria are chosen based on authors perspective on this study and feedback received from government officials of district levels under the Digital India-training programme. To address the subjectivity lies in e-Governance grey areas of sector, criteria are also weighted using fuzzy scale. Later methodology based results are presented to draw a strategic road map for strategic development of the country.

Findings – On applying COPRAS-G method to predict pessimistic, optimistic and realistic scenario of e-Governance implementation across the ten sectors, high priory order in realistic scenario of results shows that implementation of ICT applications for e-Governance should be in the sectors like Environment, Climate Change and in the Railways. Industrial Sector is also ranked as preferred one over the other sectors on the basis of e-Governance efficacy assessment.

Research implications – Here COPRAS-G method is used as MCDM techniques. However, few other MCDM techniques such as GRA, DRSA, VIKOR, SMAA, SWARA and SAW can be also explored to outrank various Indian sectors to deal with subjectivity in decision making.

Practical implications – Implementation of ICT applications to support e-Governance varies sector to sector. ICT based governance involves high degree of complexity in driving the operations for development of respective sectors. Therefore, Government and policy makers need more flexibility to overcome present barriers of sector development. Such research can support decision making where GST based COPRAS-G method is able to capture and address the breaches of information security. Moreover, management concern for sector development has been presented on the basis of i.e. pessimistic, optimistic and realistic scenario more precisely.

Social implications –The results can provide guidance to the academicians, policy makers and public sector highlights various possible measures to handle the security breaches in multi facet intention of sustainable development. The outcomes from MCDM framework can also help in drawing a rough trajectory of strategy i.e. development ICTs applications and e-Governance process.

Originality –This paper can be supplement and act as the support for decision making in conflicting situations on different flexible scenarios. Moreover, such work can synergize conflicting ideas of decision makers, academics and various other stakeholders of the Indian IT sector.

Keywords –ICT Applications, Information Security, e-Governance Efficacy, Digital India, Grey System Theory, COPRAS-G, Strategic Development, India.

Paper type –Research paper

1. INTRODUCTION

India is seen as the oldest proved civilization and she has been the closed economy in the last Century. How information is perceived in the ancient days of civilization is not clearly depicted yet. Moreover, since many decades the possibilities of her developments could not be explored the grey portions for its strategic development, specifically on e-Governance perspective. Additionally, over the period due to technical advances in science and technology, the country has begun another era of administration and governance such as e-service delivery based on information as the element (Perri, 2004). After country got the independence in 1947, not limiting to these advances, information technology (IT) adoption, various social and techno-economical risks have also opened new challenging areas to administer and to develop e-Governance models. Such need of administration is to focus them especially not only the context of territorial security but also related to various dimensions of Union and State subject list (Fenz *et al.*, 2014). Many studies support that e- Governance in various sectors of India is resilient to attacks by threats and frauds, inadvertent virus, and a variety of motivated cyber crimes. The resilience have been primarily lack of IT infrastructure primarily in villages, implantation of IT policy measure across the States those again impacted by the less literacy rate and adequate skilled manpower. In last few decades, country went through many amendments in its Constitutional provisions on these lines of challenges, specifically after the economic liberalization to strengthen the e-Governance process. On further deliberation, the practices and standards in relation to information security and its need of management led administrative reforms and recommended more use of ICT applications to support e-Governance which are seen as important elements (Tsohou *et al.,* 2010). Since e-Governance practice drives availability of infrastructure, continuity of IT services, also ensures IT systems implementation, therefore, it not only requires security of information but develop adequate infrastructure. In this reference, not only standards are limited to secure critical information assets of government against loss, theft etc. but also to ensure data confidentiality, integrity and non-repudiation (United Nations and ASPA, 2001). It was also felt that a good approach towards implementation of e-Governance is to combine short-term steps on one side and achieving sustainable development goals on the other side. In the last two recent decades, the Government of India (GoI) and many State Governments have initiated several e-Governance projects across the sectors. But given the challenges and barriers of sectors, e-Government's objective has also emerged as to improve convenience, reduce time and improve transparency in delivering the services at local grassroots levels (Holden *et al.*, 2003). In order to address such objectives, the key elements of e-Governance which are now focused in India includes e-administration, e-citizens, e-services and e-society where information security, policy implementation are found as critical base to various sector development using ICT applications. Moreover, businesses and citizens expect high standards of services, instant access to information, efficient transactions and support, whenever and wherever they need it, but in a secure fashion. Therefore, measurement of e-Governance implementation for sustainable growth or its efficacy in various gross domestic product (GDP) dependent sectors and their penetration in prioritized manner for country's strategic development found as important area to study for a research work.

1.1 Enlightening grey portions of e-Governance

In view of above background, development of e-Governance process in various sectors is seen as difficult task to implement by higher management at national level (say at the Cabinet level). Thus, it is important to assess efficacy of ICT applications as e-services depends on implementation on IT policy and information security management practices in many sectors. There are many governance related barriers across GDP sectors which hinders IT infrastructure, provide threats to policy implementation which further impacts overall e-services delivery. Such barriers are seen as grey portions or grey areas which

need to be managed properly. Grey portions of ICT based e-Governance focused on setting trade-off between technical sides of threats presents in IT-system and implementing the suitable e-Governance model (Knapp *et al.*, 2009) on the management side. To address challenges of these grey portions, the economy is looking for more possibilities and routes to expedite foreign direct investments (FDI) in the various sectors. But again justifications of those investments for social benefit order through sector developments are questioned and remained untouched. Decision making needs support and answers of those questions related to sustainability ensuing information can only be answered though efficacy assessment. Such assessment of grey portion is based on quantifying and drawing a line between optimistic and pessimistic scenario of e-Governance implementation in various sectors. In this context, the second report of administrative reforms also addressed this issue and suggested implementation of National e-Governance plan in a phase wise manner (ARC Report, 2008). Accentor has also described a method to implement e-governance: '*Thinking big, start small and scale fast*'. The interests for exploring the barriers associated with grey portion of sectors have also influenced identification of various criteria.

Therefore, it was felt to study the strategic and flexible thinking based Multicriteria Decision Making (MCDM) approaches which seems more reflexive in nature and can resolve many e-Governance issues. Such methodology can also help in drawing development trajectories those could be touching each other in the economy dependent sectors. Efficacy of e-Governance for two sectors i.e. agriculture and health are of main concern primarily due to the two reasons, firstly due to significant dependency of GDP on the agriculture sector and secondly due to the need of health as basic service to economy and also the need of common citizen. For a good assessment, MCDM based analysis adopted to deal with the issues related to criteria to criteria which can assess the impact of criteria on various sectors-alternatives. This focused study can also provide projections and roads of future sector development in line with the objectives of Sustainable Development Goals (SDGs). The present state of art and paths of strategic directions of e-Governance are seen as example various directions of sustainable development of sector alternatives (Goel and Smith, 2010). The study incorporates flexibility to support decision making which can be useful further to study robust strategic planning at the national level. Flexibility can also be modeled to get the pessimistic, optimistic and realistic scenarios of e-Governance efficacy specifically to address ICT applications in sectors. As various sectors are seen as grey areas to identify portions for more possibilities of ICT application penetration, the Method COmplex PRroportional ASsessment (COPRAS) is studied and used for comparison of alternatives (Zavadskas *et al.,* 1994). The method used in this study assumes direct and proportional dependence of significance and priority of sector alternatives on a system of criteria (Ustinovichius *et al.*, 2007).

As indicated above, ICT applications proves to play a fundamental role in the improvement of education, the battle against climate change and even the progress on gender equality, and now becomes important to ensure sustainability by finding local solutions ensuing IT security standards, policies implementation for all needs of e-services. Therefore, penetration level of welfare services based on e-Governance concept which utilizes IT infrastructure as the base need to be assessed. Thus, the objective of this study is to assess efficacy of e-Governance or ICT application penetration in various sectors. The efficiency depends on information delivery and implementation of IT-policy, and also on identification of many qualitative criteria that impact performance of e-Governance in those grey sectors.

1.2 Objective and research agenda

The objective of this research paper is to measure e-Governance efficacy in various sectors of Indian economy. For the same purpose, sectors which are identified for the study consideration includes Agriculture (ALS), Aerospace (AS), Defense (DS), Education (ES), Finance (FS), Environment and Climate Change (ECCS), Health, Industrial (IS), International Cooperation for Sustainable Development (trade, tourism and culture and bio-diversity initiatives, awareness and implementation through ICT applications) (ICCS) and the Railways sector (RS). The assessment is based on the aspects of various grey criteria which impacts overall all e-Governance (Loukas *et al.*, 2013). The research paper primarily describes and utilizes the common COPRAS and GST based COPRAS-G methodologies. To conclude, the paper also discusses about the possibilities of measurement and development of strategic trajectories for future e-Governance development. Results and recommendation are described which can enable decision making support to academicians, government, corporate and policy makers to assess strategic re-orientation of funds deployments. Such recommendation may help in closely monitoring of information as well as the national security of the economy.

The organization of the paper is as follows. **Section 2** provides literature review, gaps and research design. **Sections 3** briefly describes overview of methodology i.e. the COPRAS and GST based COPRAS methods. **Section 4** highlights the e-Governance in India. **Section 5** demonstrates an application of COPAS and COPRAS-G methods for assessment of e-Governance based on ICT applications implementation in various GDP dependent sectors. Results and discussion are provided in the **Section 6**. In the later part of the study, conclusion, limitations and future scope of work are presented in the **Section 7** followed by the implication aspects of the research study on theory, management and policy in the **Section 8**.

2. LITERATURE REVIEW

This section presents the literature review for the research study. Apart from technical codes, standards and practices, ICT applications and their need of management all elements of e-Governance are seen as backbone to support digital infrastructure, information security and privacy in various sectors. As noted earlier, many sectors are seen as grey in nature to identify and fill the gaps for digital empowerment. For the same purpose, ranking of various sector alternatives is determined using the COPRAS based MCDM framework. The GST based methodology is used to develop the various scenarios. In order to gain better insights into the various issues related to Information security, IT policy, e-Governance and administration, the literature review has been divided into various parts highlighted here. Systematic literature review approach is adopted for the same purpose. Systematic literature review has been presented by many authors in the past and defined as a systematic, explicit, comprehensive and reproducible method for identifying and evaluating the existing body of knowledge (Fink, 2005). This review included research work produced by researchers, scholars and practitioners. Under this backdrop, the section provides a systematic literature review firstly on issues related to information security, threats and IT policy implementation in the context of e-Governance and secondly reviews on application of MCDM methods in the chosen context of grey system. The literature review is organized under the following heads.

- ***i.*** Information security in the context of e-Governance
- ***ii.*** Threats in sectors and IT policy in the context of e-Governance
- ***iii.*** e-Governance, ICT applications and its administrative related issues
- ***iv.*** Review on MCDM framework to assess e-Governance, the COPRAS and GST based COPRAS methodologies

Being information is essential element to e-Governance and public administration for sector development; select papers on information security threats in various sectors were also systematically explored. Such papers and research work are provided in the following Table I.

Table I

In order to assess the objective, on the aspect of Multi-Criteria Decision Making (MCDM), many scholars have framed MCDM framework but not have assessed ranking of various types of alternatives, specifically based on many aspects of the central themed criteria. Therefore, efficacy of e-Governance in various sectors and in the economy as a whole are to be evaluated from the point of view of economical benefits, technological-adaption, ecological-environmental adaptability, also on the view of level of education and service quality (Kaspersky and Furnell, 2014). Out of many MCDM researches applied in the different connotation of measurement, Simanauskas and Sidlauskas have used this methodology during the last decade (Simanauskas and Sidlauskas, 2006). Ustinovichius *et al.* (2007), (Zavadskas *et al.* 2008c, 2008d, and 2010), Santhanam and Kyprasis (1995) have also used this technique specifically in the context of investment in the various types of alternatives.

Various authors have also widely applied GST and contributed the research using methodology applications. Out of many, few are the important research areas where authors have carried out the research, such as: Regulatory aspects of grey systems researched (Chen Mianyun, 1988), Irrigation strategy and grey modeling(Deng Julong , 1987d), Weather forecasting (Deng Julong, 1988f), Water level management Deng and Deng, 1985), Interdisciplinary science (Guo Hong, 1986c), Agriculture and rain harvesting management (Hu Congwu, 1987), Forestry management (Huang Jianer, 1987), Railways sector management (Lee Senra, 1986), Applications in industries (Meng Wanrong, 1988), Application in judicial system in China (Xiong Jiling, 1988), Selection of best web site (Bindu *et al.*, 2010), Application in construction industry (Tupenaite *et al.* 2010, Kaklauskas *et al.* 2010 & Zavadskas *et al.* 2010), Energy systems (Hasan and Zolfani, 2012) and Sustainable buildings (Kaklauskas *et al.*2005, 2006).

2.1 Research gaps

Based on the literature review on various aspects of GST applications, MCDM framework and e-Governance related issues (Refer Table I and Section 2). While carrying out the literature review, it is observed that many sectors are missing with their roles and responsibilities to implement ICT applications. It is observed that the e-Governance issues need focused approach to address them specifically when country has to play many vital roles in international cooperation, maritime security and international obligations to boost up its machinery. Thus, study is specific to Indian context as scope of investment in IT- related infrastructure and to promote secured ICT applications are needed to meet objectives of Sustainable Development Goals (SDG). Country seeks capital to support gross domestic product (GDP) by operating such sectors alternatives. One of the ways to justify utilization of such huge investments and promote FDI in various sectors is to implement e-Governance efficiently and in a mission mode projects. Further, e-Governance found as one parameter to be assessed for meeting the sustainable goals. Not only this efficacy of the Union is influenced by many criteria and also on the type of mission mode projects (MMPs). The MMPs are being implemented across the sectors (NeGP, Deity, Govt. of India, 2015-16). After doing the literature reviews, it can be said that the assessment for penetration of e-Governance in various sectors within the Indian context has not been conducted so far,

specifically considering various criteria dealing with solution for flexible decision making for developing strategic-contours for future development of the country.

In order to fill the research gaps, this paper aims to prioritize various economy dependent sectors by identifying set of grey criteria using COPRAS-G methodology. The results from the paper are highlighting the various strategic dimensions on development of future strategy to combat IT security threats to e-Governance (Doherty and Fulford, 2006). The complete framework of the research study can be understood from the Figure 1 on Research Design Flow used for the research study.

Figure 1: Research Design Flow

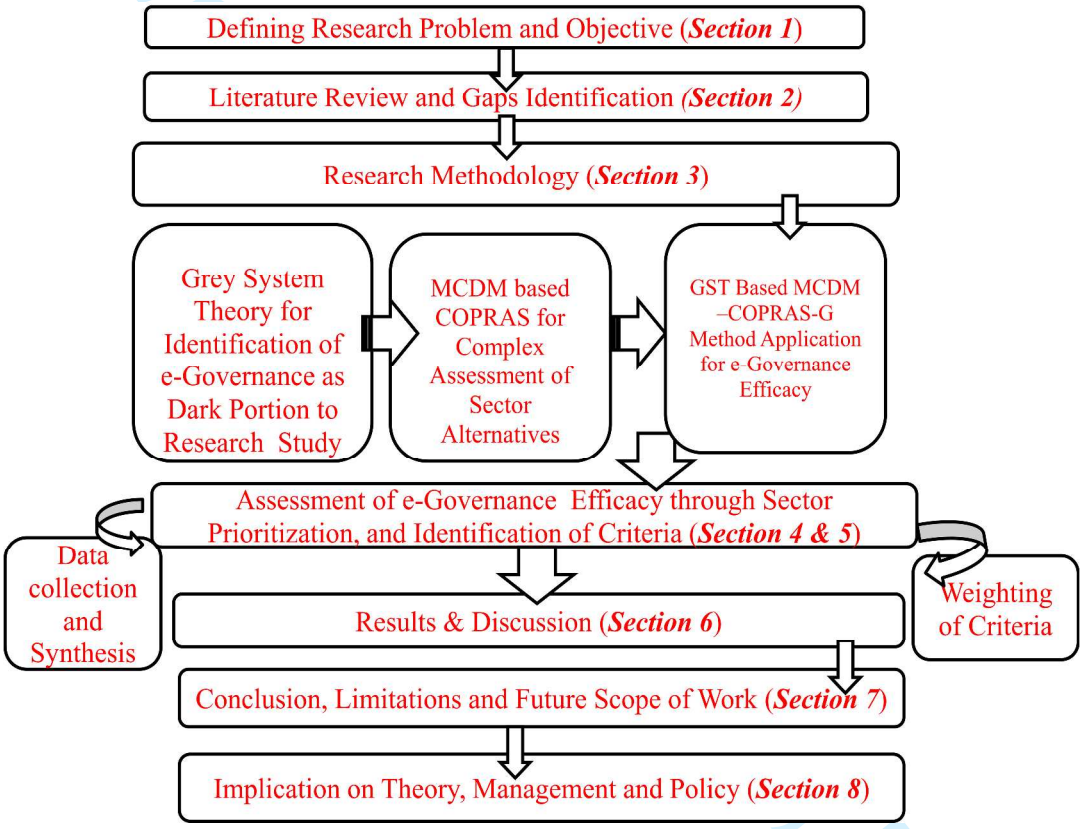

Figure 1: Research Design Flow

The next section presents overview of methodology used for the assessment purpose.

3. METHDOLOGY

As seen in the previous section, barrier and challenges of sector alternatives are seen as grey areas for effective e-Governance implementation. The challenges include barriers related to administrative reforms, NeGP, technical, economical, infrastructure and social constraints which hinders the e-Governance. These barriers are more vital to enlighten to assess digital empowerment but they still remains grey (incomplete) in nature. Quantifying sectors priority on the point of view of penetration of ICT application in various sectors can be good option to deal with grayness of flexible solutions to support decision making. Reasons associated with Indian context of study are more important as ICT applications and their penetration varies sector to sector. Not only this sectors are impacted by many barriers constraints and

affects it ICT applications or in a way to say efficacy of e-Governance. Thus, research study seems to be demanding and found not ever to be measured. Moreover, it is seen from the literature review that research on those lines has been never analyzed yet. Therefore, this research study adopts Indian context and selects various sectors as alternatives for measurement of e-Governance efficacy.

In this connection, the Grey System Theory (GST) based application found to be helpful methodology to capture the pessimistic, optimistic and realistic snap shots of e-Governance. Julong noted that GST systems are information-less systems and classified as Grey Systems (GS) (Deng Julong, 1982, 1988). The word 'Grey' means poor, incomplete and uncertain. The theory includes grey elements and grey numbers (usually denoted by the symbol⊗). Julong (1988) elaborated that GST applications are multi-disciplinary and can be applied in variety of specialized areas. The main objective of addressing the Grey System is to establish as a bridge the gap that exists between problems of society and nature. It is seen that the development of GS and its theoretical aspects are coupled with practical applications in various areas of management. Julong (1982, 1989) also mentioned that flexible MCDM for sustainable planning cannot only just as a tool for securing the boundaries but it can also help in development of right strategies for the future. However, in the literature development on futuristic scenarios are found very limited, specifically on Indian context. It is strongly felt that ignoring such effective MCDM based applications raises few sets of big questions in the minds of academicians and policy makers in the present changing need of IT sector. In the nutshell, such assessment of e-Governance in risk-arena of information security related to e-Governance which includes vulnerability to the nation as the one boundary and becomes very important to study.

On methodological fronts, the study chooses a MCDM method based on GS theory application. Many of the select sectors are grey in nature where assessment of ICT application or its penetration for public service is difficult. The complete set of sectors seen as grey system in the Indian economy and in order to assess the range of ICT applications initiatives being support by various MMPs in different sectors, such methodology was required as opposed to other approaches which can build of criteria to criteria assessment of sectors and develops three scenarios for possible strategic development.

The main idea of COPRAS-G method was firstly presented by Zavadskas (2008). The technique expressed criteria values in intervals that are derived from real situation of decision making and GST applications (Deng 1982, 1989). Many other authors have also used the technique which has emerged from grey decision making theory which deals with problems of uncertain environment. The technique suits where incomplete information is available to seek possible solutions (Chang *et al.* 2010, Lin *et al.* 2008 and Maity *et al.* 2012). The method presents level of information into three levels such as white number, grey number and black number (Maity *et al.* 2012). The white number is an exact number, i.e., lower limit is equal to the upper limit which provides complete information. Where, the upper and the lower limits are all grey numbers. While a black number has neither upper nor lower values of limits. Therefore, it is said that it has no meaningful information. As per the author Zavadskas, a grey number has upper and lower limits with limited information, i.e., whose exact value is unknown but the interval within which the value lies is known (Zavadskas *et al.* 2008, 2009).

In the following sub-sections, a brief overview on the common and GST based COPRAS are described. For in-depth details, research papers on GST based COPRAS method be referred Zavadskas and Kaklauskas (1994). Following are the various steps to apply the common COPRAS and GST based its applications (i.e. COPRAS-G).

3.1 Common COPRAS method

This technique is commonly presented in many MCDM applications and research studies (Zavadskas *et al.* 2001, Vilutiene & Zavadskas 2003, Zavadskas *et al.* 2004, Kaklauskas *et al.* 2005, Kaklauskas *et al.* 2006 and Zavadskas *et al.* 2008b). The problem framing algorithm of calculations in the COPRAS method is the same as in case of other MCDM ranking methods. The methodology implementation starts with building an initial decision-making matrix from *(n)* alternatives described by *(m)* criteria, thus set { *fij* }, where, $i = 1, \ldots, m$, and $j = 1, \ldots, n$. The weights of the criteria are presented by q_j, where, $i = 1 \ldots m$. Then calculating the weighted normalized matrix, where comparison of criteria expressed in different measures which demands for transformation of the criteria into dimensionless (i.e. normalized) values. This stage aims to obtain normalized weighted values from the comparative criteria. When the dimensionless weighted values are known, all criteria expressed in different measures are compared. The following steps and formulae are used for this purpose. The formulae are shown in the various equations as indicated in the ***Appendix-A*.**

In order to measure e-Governance efficiency in various sector-alternatives, using this method assumes direct and proportionate dependence of significance and priority of sector alternatives on a system of criteria (Ustinovichius *et al.* 2007). The determination of significance and priority of alternatives can be explained in four steps (Viteikiene and Zavadskas 2007). The calculations used by formulae shown in the equations (1) to (6) as indicated in the ***Appendix-A***.

Step1. In this step, the normalized decision-making (DM) matrix is framed. For the same purpose of comparable and dimensionless values of sector alternatives, the normalization procedure is used. The Equation (1) of *Appendix-A* is used in normalizing the decision matrix (M) (Zavadskas *et al.* 2008a).

Step2. In the second step, the sums of weighed normalized criteria describing the *i*-th sector alternative are calculated. In COPRAS method, each alternative is described with its sum of maximizing attributes $C_{+i,}$ i.e. optimization direction is maximization, and minimizing criteria $C_{-i,}$ i.e. optimization direction is minimization. In order to simplify the calculation of $C_{+i,}$ and $C_{-i,}$ in the decision-making matrix columns, firstly all are placed in maximizing criteria and then minimizing criteria are placed. In such cases, $C_{+i,}$ and C_{-i} are calculated using Equation (2) and (3) as shown in the ***Appendix-A***.

Step3. Calculation of the relative weight of each sector alternative. The relative weight (Q_i) of *i*-th alternative is calculated using Equation (4) and using this equation, the relative weight (Q_i) can also be written in simplified form as Equation (5) of the ***Appendix-A***.

Step4. Determine the priority order of sector alternatives (let's assume sector-alternatives are (S_i). The priority order of compared sector alternatives is determined on the basis of their relative weight. The alternative with higher relative weight has higher priority (rank), and the alternative with the highest relative weight is the most acceptable alternative. The priority order weights are calculated using the Equation (6) as indicated in the ***Appendix-A***.

The complex proportional assessment method with values determined in the intervals i.e. white and black is used (Zavadskas *et al.* 2008b) because many decisions are made in real-world situation or in realistic sense where criterion values are not precisely known but also can be expressed in the form of intervals (Zavadskas *et al.* 2008b; Zavadskas *et al.* 2009). The stage wise procedure for this method is described in the following sub- section 3.2.

3.2 Grey System based COPRAS Method

This section shows the detailed procedure involved in measuring e-Governance efficacy in various sector-alternatives when criterion values are expressed with combined use of crisp and interval numbers. The MCDM technique utilizes criterion values determined in intervals instead of using crisp values. Replacement of the crisp (x_{ij}) with the interval values $[\underline{x}_{ij}, \overline{x}_{ij}]$, where $\underline{x}_{ij}$ is the lower limit and $\overline{x}_{ij}$ is the upper limit of interval, requires some modifications in the ranking procedure and it manifest themselves in *Step1* and *Step2* as described in the previous sub- section.

In *Stage1*, use of intervals has effects on the normalization of criterion values. The normalized values of decision-making matrix whose elements (intervals) are calculated as using the Equation (7) and (8) of the ***Appendix-A*** (Zavadskas *et al.,* 2008b, Hwang and Yoon, 1981). While in *Stage2* intervals has an impact on formulas used for calculation of $C_{+i,}$ and $C_{-i.}$ Then, the sum of maximizing criteria $C_{+i,}$ of *i*-th alternative is calculated using the Equations (9) and (10) as shown in the ***Appendix-A***.

Now all the steps of COPRAS method (which are used in the *Stage1*), are modified with interval values and various steps of COPRAS-G methods are shown here (i.e. *Stage2*).

Modified Step1. *Modifying and constructing COPRAS based DM matrix.* For the MCDM problem that simultaneously uses the lower and upper limits of the selected criteria, the decision matrix can be expressed as indicated in the matrix Equation (11).

Modified Step2. *Normalizing the DM matrix.* The normalized values of decision-making matrix are calculated using formula (1) for criteria with crisp values and using (7) and (8) for criteria with values expressed in intervals.

Modified Step3. *Determining the criteria weights.* The procedure of determining the criterion weight is usually not an integral part of many significant multi-criteria decision-making methods. However, the criterion weight may significantly affect to the obtained results due to which different researches suggest different criteria weighing techniques and this paper uses fuzzy synthetic extent analysis of Chang (Chang *et al.,* 2008) for weighting of various grey criteria.

Modified Step4. *Calculate sums of maximizing criteria, for each alternative*. When the decision-making matrix contains criteria with crisp and criteria whose values are expressed in intervals, the sums of maximizing criteria can be calculated using Equation (12).

Modified Step5. *Calculate sums of minimizing criteria, for each alternative.* Similar to the previous step, the sums of minimizing criteria are calculated using the Equation (13).

Modified Step6. Calculating the relative weight Q_i of each alternative, by formula of equation (12) *(Refer Appendix-A)*.

Modified Step7. *Determining the priority order of alternatives.* The priority order of alternatives is determined on the basis of their relative weight, and alternatives with higher relative weight have a higher rank.

Modified Step7. Determining ranking of sector-alternatives according to e-Governance penetration, by using formula as indicated in Equation (13) ***(Refer Appendix-A)***.

In the above context, a fuzzy set is given by a membership function *f(x)*. Triangular Fuzzy Number (TFN) is a special type of fuzzy set, and can be denoted as $TFN = (m, a, b)$. Where, *(a)* and *(b)* are the lower and upper limit in the support of TFN respectively, and *(m)* is the mid-value of TFN. The general representation of a fuzzy number is given in the Equation (14) (***Refer Appendix-A***) and Equations (15) to (18) refers to the algebraic functions i.e. theirs addition, multiplication, scalar multiplication and division. To compare two different fuzzy numbers, an index is calculated using equation (19) which is also referred as Yager Index (Yager, 1981, Bilsel *et al*., 2006). This research paper considers the fuzzy synthetic extent analysis method developed by Chang for calculating the weighs of various criteria (Chang *et al*., 2008).

4. THE e-GOVERNANCE IN INDIA

This section presents e-Governance related issue which covers brief overview of administrative reforms, the National e-Governance Plan (NeGP), Digital India Programme: The e-Governance initiative, Reforming governance through technology, ICT in financial inclusion for Digital Divide, the National e-Governance Plan (NeGP), various Mission Mode Projects (MMPs) and push from sustainable development goals in the context of the research objective.

4.1 Administrative reforms

Undoubtedly, as is true for other countries in the world, in India to ICT applications are becoming the main driving force in every sector. Till today central sector schemes and concept of financial inclusions did not dramatically change the scenario of government-citizen interactions in the last Five Year Plan. Citizens also did not benefit much as they still continued to physically go to each department to avail the public services. Moreover, there was not relevant integration of information happened within or amongst the departments and every government department continued to offer only silos of public information. The lack of consolidation of related best practices at one place that leads to 'reinvention of wheel' in various states at the same point of time was found as one of the reason for the same. Eleventh report for second Administrative Reforms Commission had identified the potential of e-Governance and tried to encourage its speedy spread (ARC Report, 2005). Later the evidence of governance in e-government procurement got more focused to use more and more ICT applications (Rotchanakitumnuai, 2013) and had given the genesis of the Governance based on e-services.

4.2 National e-Governance plan (NeGP) and Mission mode projects (MMPs)

Based on recommendations from ARC committee, GoI launched the National e-Governance Plan (NeGP) with the objectives to make all government services available to the citizens through electronic media. The plan mission is to make all Government services accessible to the common man and to ensure efficiency, transparency and reliability at affordable costs. Contextually, the NeGP strategy is to realize NeGP vision through centralized initiative, decentralized implementation and central role of line ministries with the emphasis on public private partnerships (PPP) (Chandrashekhar, 2005). Moreover, the plan has also given Right to Information Act (RTI) as tool (Singh and Karn, 2012), strategic framework for good governance through e-governance optimization and tried to implement in many states (Kalsi and Kiran, 2015).

4.3 Digital India: The e-Governance initiative

Over the years, in order to address need of future economy to create changes both in attitude of civil society and create IT policy framework, GoI has launched Digital India Programme in 2015 with the much more extensive and higher than the NeGP. Previously many studies explored the importance of

citizen participation and involvement in e-Government projects (Azelsson K. *el al.* 2010). While NeGP, affirmed in 2006 is more concentrated on e-governance, creating and providing core ICT infrastructural base to speedier administration delivery. There were 31 Mission mode Projects (MMPs) in NeGP, which are further classified as state, central or integrated projects. On this side, Digital India Programme comprises of three key areas of visions based on the nine pillars for implementation. NeGP has been focused on e-Governance and one of its main goals was to create and provide core ICT infrastructure to enable them in the delivery of e-Governance services. While Digital India programme is far away from it and aims at transformation of the country into a digitally empowered society and knowledge economy through application of ICTs. Based on the facts and data submitted to International organizations has estimated country's position of e-Governance transformation through Citizen Participation Index and e-Governance Index. Country's position indicates not only about transparent governance also depicts emerging situation of Indian in the South Asian and Pacific region (Wescott, 2001).

4.4 Reforming government through technology

Government Process Re-engineering using IT to improve transactions is the most critical for transformation across governmental sectors. Accordingly the government is also disseminating e-transactions and measure statistics of National and State level e-Governance projects including MMPs. The scheme of e-Taal receives transaction statistics from web based applications being monitored periodically on near real time basis. However, GoI's guiding principles for reforming government through technology forms simplification and field reduction, online applications, tracking of their status and interface between departments should be provided. Use of online, integration of services and platforms, mandate of electronic databases, workflow automation inside the Government and public grievance redressal through IT mode are being implemented.

4.5 ICTs in financial inclusion for digital divide

Rangarajan Committee report suggested creation of the Financial Inclusion Technology Fund (FITF) with the objectives to enhance investment in ICTs. The report aimed at promoting financial inclusion and stimulating the transfer of research and development to increase the technological absorption capacity. Financial infrastructure is supported by banks like NABARD and SIDBI. These banks have designed and developed the Self Help Group (SHG)-Bank Linkage Programme (SBLP) through which it has provided billions to banks covering their lending to SHGs. Although the number of SHG's linked with banks have increased but the size of the disbursed loans hasn't shown the same trend. In one of the study conducted by the Institute for Financial Management and Research (IFMR) indicates that inclusion drive did not have any major impacts.

4.6 The 17 SDGs for India: Digital transition

This recent shifting of Millennium Development Goals (MDGs) to SDGs created through a collaboration of the UN Development Programme (UNDP) and the UN Development Group (UNDG) is clearly seen. Where the MDGs where quite narrow in focus, the SDGs are set out to tackle a whole range of issues. Comprehensively, the 17 SDGs are very ambitious, targeting at end poverty, extreme hunger, ensure quality education for everyone, improve healthcare, end gender inequality, protect, restore and promote sustainable use of natural resources, etc. to improve social and economic development and end inequality. All SDGs are now targeted by GoI specifically in backward areas such as red corridor and north-eastern states for the development. Many organizations questions how world can and nations can achieve SDGs by 2030? This is not necessarily catastrophic, since the goals are designed to be self-consciously

ambitious and encourage extra efforts. Still, it's true that more action and awareness are needed nowadays. At the outset, the Education is one of the most powerful instruments for reducing poverty and inequality and lays a foundation for sustained economic growth. Yet, many children in developing countries like India lack access to quality education and knowledge. The improvement of quality education for all is not the only SDG where ICT plays a major role. In this context, Luis Neves, the Chairman of the Global e-Sustainability Initiative (GeSI), underlined the importance of ICT in relation to challenges of climate change.

5. MESAURING E-GOVERNANCE EFFICACY

Based on the background presented in the previous section, this study measures efficacy or penetration level of e-governance in various sector alternatives. This section presents selection basis, sector identification and their description in the following sub-section.

5.1 Sector selection

This sub-section presents the selection of sectors for research analysis. Presently, e-Governance in India needs to support challenges of climate change and its adverse impact on the economy. The efficacy of e-Governance at the Union government level can be assessed by considering those sectors which are relatively more contributor of GDP in Indian economy. Historically, country has classified and tracked its economy and GDP as three main sectors i.e. Agriculture, Industry and Services. Among all of three, the Agriculture includes crops, horticulture, milk and animal husbandry, aquaculture, fishing, sericulture, aviculture, forestry and related activities. Industry refers to the people or companies engaged in a particular kind of commercial enterprise. It is described it as the manufacturing of a good or service in the country. The services sector is not only the dominant sector in India's GDP but also attracted significant foreign investment flows, contributed significantly to exports as well as provided large-scale employment. The service sector covers a wide variety of activities such as trade, hotel and restaurants, transport, storage and communication, financing, insurance, real estate, business services, community, social and personal services, and services associated with construction. In the recent years, the government recognized the importance of promoting growth in services sector and provided several incentives in wide variety of sectors such as health care, tourism, education, engineering, communications, transportation, information technology, banking, finance, management, among others. With this broad classification and interest of this scope, the study selects the list of 10 major sectors for measuring the e-Governance efficacy.

Out of these ten (10) sectors included two other sector segments namely environmental degradation and climate change, and the international cooperation. For the better understating these sectors are expressed as S_j *(j=1, 2, 3, 4, 5, 6, 7, 8, 9, 10)* and for better understating each sector is denoted as (S_1), (S_2), (S_3) (S_4) (S_5) (S_6) (S_7), (S_8) (S_9) and (S_{10}).

5.2 Identification of grey criteria

Based on the literature review, research gaps, it is found that the criteria can affects delivery of government initiatives and are related to IT infrastructure adoption, policies (existing and old), incidence of security breaches (Doherty and Fulford,2005), investment, impact of IT-initiatives on supply chain performance, improvement in service delivery of central sector scheme, penetration of literacy rate (i.e. digital literacy), political and executive adaptability (e-Cabinet plan), IT policies initiatives to fuel overall

economic growth, impact of sector threat to national and other maritime security related issues and IT for jobs etc.

In line with the present and futuristic trends of strategic development of ICT applications in select sectors, out of many only fifteen criteria are considered here. Here criteria are selected based on feedback received during various training programmes for district level of officers under the Digital India programme to develop skill and future requirement of manpower. Based on personal interviews conducted during the training programmes over the one year and referring to annual reports, estimates of budget plans for IT development in each sector, criteria identification and feedback on e-Governance efficiency is assessed. (NeGP Awareness and Skill Development Program, Deity, GoI). Inputs from such training are taken due to position and role of district in the Indian architect of administration to pass and distribute benefits of central sector schemes to make accessible to the citizens. Such assessment and sector ranking can be useful to draw futuristic strategic roadmap to secure national security in the context of sustainable development and financial empowerment of the sectors.

Since MCDM framework application is based on GST, these criteria are known grey criteria identified and shown in the Table II (a). The brief descriptions of these grey criteria are given in the Table II (b). Table II (a) also shows criteria orientation for their optimization (maximum or minimum) purpose. The next sub-section highlights about the description and weighting of criteria.

5.3 Weighing of criteria

To measure efficacy of e-Governance, criteria are selected and weighted using fuzzy synthetic extent analysis. Section 5.2 described the selection of sectors and following Section 5.4 discusses the computation of criteria weights.

Table II (a) and Table II (b)

5.4 Grey criteria weighting

Here fuzzy decision matrix 'M' is constructed to measure the relative degree of importance to each criterion based on fuzzy 6-point linguistic scale (*Refer* Table III), is given in Table IV (indicates fuzzy values). Table IV shows relative importance among all 15 grey criteria considered ranking of sectors for e-Governance. The assessment is on the basis of weights assigned. For the same purpose, the fuzzy synthetic extent analysis of Chang *et al.,* 2008 is applied. The methodology of the extent analysis is shown in the ***Appendix-B*****.** The weights obtained from fuzzy synthetic extent analysis are considered in COPRAS and COPRAS-G assessment for ranking of ten economy dependent sectors.

Table III and Table IV and Figure 1

Figure 2 presents interdependency of all criteria on each other as coefficient of correlation is estimated (represented by term R^2, whose come out 0.286). Figure 2 indicates that criterion political interference and efforts to promote concept of e-Cabinet (C11) should be minimum, and support for employment rate (C13) and overall sector support to GDP growth (C14) should be maximum as their weights are relatively high.

5.5 Orientation of grey criteria

Based on various methodology steps, the maximum and minimum orientation of each grey criteria are selected in order to assess e-Governance efficacy or e-Governance initiatives penetration in each sector. The COPRAS-G method gives realistic scenario in estimating the ranking of the sector alternatives. The next sub-section presents results arriving from MCDM based COPRAS-G application.

5.6 Prioritization using COPRAS-G

Once criteria weighting and their orientations is fixed, various steps of COPRAS-G is applied for prioritization of sector alternatives i.e. S_j *j=1, 2, 3, 4, 5, 6, 7, 8, 9, 10*). Various steps of COPRAS –G method presented in the Section 3 are applied here. In the Step1, all sector alternatives are compared for all grey criteria using fuzzy scale (*Refer Table III*). Criteria Vs sector- alternatives decision matrix 'CA' is formed where criteria values are assigned on pessimistic and optimistic values of fuzzy numbers. Weighted sum method of all the criteria column vectors is assumed in framing of normalization of 'CA' decision matrix. The criterion values are determined in intervals instead of using crisp values. The all crisp values of criteria with respect to sector- alternative are assigned and taken as in the case of normal COPRAS method. Later, all crisp (x_{ij}) values are replaced with the interval values $[\underline{x}_{ij}, \bar{x}_{ij}]$, where $\underline{x}_{ij}$ represents lower is limit and $\bar{x}_{ij}$ represents the upper limit of interval. The normalized values of decision-making matrix whose elements are intervals are calculated as using the Equation (7) and (8). Then sum of maximizing criteria i.e. $C_{+i,}$ of *i*-th sector-alternative is calculated using the Equations (9) and (10) as shown in the Table V, VI and VII for different scenarios.

Table V highlights sums of sum of maximizing criteria (M_j) and minimizing the criteria (R_j) for each sector alternative for the pessimistic scenario. The relative weight or significance (Qj) associated with each sector- alternative is calculated by using formula (5). Table V determines the priority orders of alternatives which are calculated on the basis of their relative weight and alternatives with higher relative weight have a higher rank. The most penetrated sector -alternatives are highlighted in the Figure 2. Similarly, optimistic and realistic (interval values) are shown in Table VI and VII respectively.

Table V, Table VI & Figure 2

The above method is a rather simple way to evaluate and then to sort out the most efficient variants (Zavadskas *et al.*, 1994). The higher is relative significance or weight (Qj), the more penetration of ICT applications in sector alternative. For example, sector has a higher priority, if (Q_1)> (Q_2)> (Q_3), then the first sector alternative is the best. The efficiency degree (N_j) of the each sector-alternative (S_j) is estimated. It shows the percentage by which the alternative is either better or worse than the other one. Formulae for relative significance and efficiency degree are shown in the ***Appendix-A***. The next section present analyses of all results obtained from the COPRAS-G application.

6. RESULTS AND DISCUSSION

6.1 *Results*

On applying, various steps of GST based COPRAS method to assess e-Governance, the results are presented in the various forms of ranking scenarios related to sector-alternatives (Refer Table V, VI, VII and VIII). It is observed that based on ranking of obtained from pessimistic scenario, Agriculture sector (S1) has shown highest efficacy of e-Governance which outranks high among all ten sector-alternatives, followed by Health (S2), Education (S3), Finance (S4), Industrial (S5) in first five. While, based on values of optimistic scenario, MCDM applications ranks Industrial (8) on first priority, International

cooperation (S9) on second position, Agriculture (S1), Environment and Climate segment (S4) and Finance (S5) comes third, fourth and at fifth position, while Defense sector (S3) ranks at the last position.

Table VII, VIII and Figure 3

Since judgment is based on single expert and on fuzzy scale as shown in Table III, the results from optimistic scenario are different from pessimistic scenario. Ranking position of Aerospace (S2) and Defense (S3) are example of such case of pessimistic and optimistic scenarios where the project gets position approximately either of side. However, the same sector-alternatives (S2 and S3) get shifted on high ranks on interval values or realistic sense for e-Governance. Table V, VI and VII shows, the efficacy conditions calculated using the various equations *(See Appendix-A).*

A single form of representation for all three scenarios is shown in the Figure 3. The Figure 3 shows different ranking of sector-alternatives given in different scenarios. The figure representation forms a decagon view where each sector-alternative is represented as node and their relative positions are indicated here. From this Figure 3, it is clearly seen that e-Governance efficacy is high in Industrial (S8), Education (S2) and Health (S3) sectors as compared to others as it ranks high in all three scenarios. However, sector like Environment and Climate Segment (S6) comes at least position in totality.

Figure 3

Since grey criteria impacts less to Industry to adopt e-Governance, highly affects the Environmental and Climate segment (S10) which is found on less priority on realistic sense. This signifies high promotion of environment protection and climate change mitigation using ICT applications for investments in suitable IT infrastructure.

Based on the analysis, this has been also observed that the priority order and ranking of the sector-alternatives in different scenarios are slightly differs. This difference is due to variation in linguistic scale of fuzzy and quantification of qualitative criteria scaled in the different scenarios. As already indicated, GST provides scenario between black and white numbers, the ranking obtained by GST versions is more precise in nature as it captured the grayness lies on e-Governance. Based on methodology, the sector ranking provides many reasons and e-Governance issues associated with sector alternatives. Those are presented in order to their interval ranking and given as follows.

6.1.1 Agriculture sector (S1)

The Agriculture sector leaves others sectors far behind in many aspect. The sector includes allied areas as well. ICT applications and their roles in agriculture have primary focus on farming empowerment and support good produce. Along with this ICT in agriculture offers a wide range of solutions to various challenges. But there are many barriers to overcome for ICT utilization. Term e-Agriculture continues to evolve in scope as new ICT applications continue to be harnessed in the economy. Given the conditions of farming sector and also the shortfall in the monsoon across the many Indian states, there are many e-Agriculture initiatives which have taken under the umbrella progarmme of Digital India Programme. Such initiatives put this sector on the fifth position leaving many barriers of distribution system to the common citizen and empowering farmers to avail direct benefits.

6.1.2 Aerospace sector (S2)

ICT has played major role in counterfeit surety related issues and supported governance in the Aerospace sector. Since very long time, the space sector has always been assisted by other countries for its operations and mission. Aryabhata mission, which was started in 1975 to till date, the country has seen many reforms and achieved various challenges of technology. The space sector is primarily governed by technology, investment, research and development activities. The sector includes operations of airports and developments in spacecraft's sector. There have been many changes from pre to post liberalization period due to technology up gradation and sector is greatly influenced on automatic- electronic infrastructure based ICT applications.

6.1.3 Defense sector (S3)

On the assessment of e-Governance, Defense sector ranks seventh. The country is largest importers of conventional defense equipments and spends near about 40% of its total defense budget on capital acquisitions. A large number of Indian private companies and publicly funded research laboratories are looking for international partners. Such trade on technologies shows e-Governance efficacy to support administration. Based on COPRAS-G application, sector secured eight where it is observed with the large potential to support, creating of suitable industries, making country self reliance and secured its national boundary separated from economies in Asian Region.

6.1.4 Educational sector (S4)

Educational sector secured second position for e-Governance implementation. India has one of the largest higher education systems in the world. Various international forums show that ICT proves to play a fundamental role in the improvement of education. The importance and role of education sector in e-democracy put the country at second position on e-Governance parameter. The ICT applications not only supports increasing demand of upcoming skilled labor force but also help in mitigating climate change through educational tool to progress, support poverty, literacy and of gender equality. Lastly it also ensures sustainability to the economy.

6.1.5 Finance or fiscal sector (S5)

The fiscal sector in India entails banks, financial organization, markets and services. Moreover, the sector is classified as organized and conventional sector that is also recognized as unofficial finance market. Fiscal transactions in an organized industry are executed by a number of financial organizations which are commercial in nature and offer monetary services to the Indian society. This sector outranks at sixth position on various criteria of e-Governance efficacy. High economic growth in the past decade has lead to huge economic inequality in ICT applications which strongly supports the growth and inclusiveness of the banking sector. Thus, sector facilitates an inclusive economic growth. ICT applications are not only are improving the efficiency of the banking by strengthening the back end administrative processes but also bringing down the transaction costs for customers which have been the major focus of the ICT for financial inclusion. Various initiatives have been also taken by the finance sector and using ICT as an important tool for fulfilling them.

6.1.6 Environment and climate foot print (S6)

Climate change has emerged as another area to tackle its impact on various sectors. International debates in forums supports that ICTs can improve environmental performance and address climate change. The biggest gains for smarter environmental, economic strategies, applications are in power generation,

distribution, buildings and transportation (Sealy, 2003). These are three areas which contribute to the bulk of greenhouse gases. In the recent years, applications of smart ICTs have emerged which can play a key role in addressing the green growth challenges in energy, transport and water management. Further, environmental benefits of ICT applications are evident in the areas such as water management, biodiversity protection, pollution reduction where innovation in ICT is the key to achieving ambitious Carbon Di-oxide emissions reductions. How can ICTs slow down global warming, improve environmental performance using smart networks, grids and industrial process and spearhead the economic recovery are the big concern. ICT companies can punch above their weight in the fight against climate change. But there is lack of awareness of this potential in expert and policy communities beyond the ICT sector.

6.1.7 *Health sector (S7)*

The use of ICT has grown considerably in recent years and has triggered a great deal of interest in an age of rapidly-spreading epidemics that don't respect national boundaries and transforming the very nature of healthcare. As compared to industrial and education sectors, the health sector's performance is often suboptimal due to an increased burden of many factors. It has been seen that ICT applications has the potential to impact almost every aspect of the health sector. In addition, beyond the formal health sector, the ability of impoverished communities to access services and demand a healthcare system that responds to their priorities and needs can be significantly influenced by broader information and communication processes, mediated by informed decision making.

6.1.8 Industrial sector (S8)

The sector secured first position on the aspect of many criteria of e-Governance or penetration of ICT applications. Main reason for securing first ranking as ICT applications in the industries have been attracting significant amount of FDI in the last few years. The constant rise in investment by Small and Medium Enterprises (SMEs) in the ICT applications demonstrates the potential of e-Governance, increase in security maturity levels and preparing against IS threats (Alencar *et al.*, 2010; Chang and Yeh, 2010). This is also one of the vital reasons behind the SME growth in such applications. Industries in India fully utilize the permissible limited of 100% FDI which is allowed in Indian IT sector under automatic route. Previously, the Indian economy was of closed type and the government enterprises controlled all Indian market. The ICT sector has become the preferred choice for Foreigners (say Non-Resident Indian and Person of Indian Origin), domestic investors and very recently choice has led to highly attractive industrial and investment policies.

6.1.9 International cooperation (S9)

On comparing the segment of international cooperation with the other sectors, the segment depicts fourth position on the assessment of e-Governance efficiency. The international cooperation operations are considered under the areas of trade, tourism and impact on culture of ICT applications. In the recent years, uses of ICT have become mandate to survive and progress. One of the UN global targets is to make available the equal benefits of new technologies, especially ICTs to all UN members. It includes developing countries and other countries affected by political or may be economical transformation. Relatively good ranking by COPRAS-G methods may be due to country's number of cooperative and collaborative programs which are initiated internationally.

6.1.10 Railways sector (S10)

Indian Railways (IR) oldest among the sectors in economy has been a pioneer in the introduction of computerization in its major areas of activities. This sector ranks ninth position and it has given every field of rail operations and business. Since then, customer management, which includes booking of tickets, freight and parcels, have seen successful ICT applications. The Passenger Reservation System (PRS), Freight Operations Information System (FOIS), Unreserved Ticketing System (UTS), Parcel Tracking System (PTS) are important examples of successful implementations of ICT applications in the sector. The proposed ICT solutions in the Indian railways sector are demand forecasting, scheduling, procurement and contract handling and office automation. In coming years, it is expected that sector has to be sufficiently strengthened at both the centre and in the regional levels to implement ICT solutions for procurement, contract handling, office automation and human resource management.

7. CONCLUSION AND RECOMMENDATION

This research paper set the priority order of ten GDP dependent sectors in Indian economy and measured efficacy of e-Governance. Ten sector alternatives were selected and then compared on the basis of identified grey criteria. For this purpose, fifteen criteria were considered for measuring e-Governance and weighted using GST based COPRAS method. These grey criteria are selected based on the aspects penetration of ICT applications to support governance. The brief concluding remarks from the study are as follows:

- On applying GST based COPRAS method for determining the e-Governance efficacy, the results from pessimistic scenario of GST based COPRAS-G analysis shows that sector like Agriculture, Industrial, Education, Environment and Climate Change segment are ranked relatively high as compared to other sectors in the economy.
- While on the optimistic scenario of MCDM analysis recommends Industrial sector as the most penetrated by ICT applications and the scenario provides Defense sector at the least order in the ranking on assessment of e-Governance efficacy.
- At the outset of three scenarios, the realistic situation of efficacy i.e. based on interval scenario supports the results that Industrial and Education sector should be on priority which have impacted relatively more by e-Governance initiatives.
- Overall, the research study provided the ranking of ten GDP dependent sector-alternatives. However, more in-depth, separate study related to other sub-sectors can be taken in the consideration.
- In addition, to COPRAS and COPRAS-G methods, other MCDM techniques such as VIKOR, TOPSIS and PROMETHEE can also be used to address the same (Albadvi, 2004). Besides outranking, criteria selected in this study can also be determined using other methods like SAW, SWARA. Some strategic assessment tools can also be used to map strategic intent of e-Governance efficacy on the aspect of real scenario obtained in this study.
- This research study with the operations cum long term strategic intent for various sector developments can support implementation of Digital India Programme towards Indian objectives of SDGs.

8. IMPLICATIONS ON THEORY, MANAGEMENT AND POLICY

This research study provides an opportunity to readers from academia, government and IT industry that addressed some of the concern related to various sector developments based on need of e-Governance

efficacy. The study conjectures the implication on theory, management and policy for respective categories of readers. Theoretically, Grey Systems are generally complex in nature and grey area evaluation on set objective is required on the basis of identification of various criteria. The theory built on selective criteria related to information security implementation, need of management and addressed barriers related to ICT applications. The GST theory also provides selection of various decision making criteria which are expressed in the intervals, where criteria values towards futuristic values can be shown in the form of interval values i.e. realistic one. The study found very helpful to assess sector- alternatives where analysis is carried out based on the pessimistic, optimistic and realistic scenarios. Thus, theory application can effectively assess priority order of penetration in realistic sense of ICT applications and measured e-Governance efficacy in this chosen context of Indian study. Moreover, MCDM based COPRAS method as the theory application to ICT applications provides enough flexibility in the decision process say to support overall governance process in this case of research. To the central core of the analysis covered in the research, weighting of criteria on fuzzy scale addressed the subjectivity lies in decision making and created the range of decision making platform based on interval values which differ from say white (i.e. optimistic) to the black (i.e. pessimistic) scenario. In a nutshell, this study on GST application paves important roles to identify the grey areas of those sectors which are less penetrated by ICT applications. It is believed that governance can be improved by various decisions making and initiatives on priority orders obtained from this GST based MCDM theory application.

It is also seen from the literature that there are many challenges to indentify need of interoperable architecture for enabling Wi-Fi networks which primarily need digital infrastructure privacy, information security guideline management and related regulations. On the same dimensions of challenges, this study may be useful managing the various sectors of the Indian economy for e-Governance purpose. Overall, the output of alternatives ranking minimizes the conflictions and provides more flexible range of decision making support for sector prioritization and their re-orientations for the near future. Therefore, such management oriented assessment can support in identifying the right directions for various sector development to align sectors strategic intend so that strategic contours can also be outlined and mapped accordingly. Thus, this research study becomes more important which has important implication on the management perspective where study can fill the research gaps in the research, academia, Indian IT sector and also in decision making support to higher administration by synergizing the minds of various actors engaged in e-Governance process targeted in Digital India Programme.

Lastly it is seen that in developing country like India, many projects of e-Governance implementation have failed while others have added very little value. Most of the reasons for failure of partial success are related to improper utilization of funds on IT infrastructure and to address the other barriers for policy development. ICT applications need IT infrastructure based tools to manage various challenges of sustainable goals. Thus, measurement of e-Governance efficacy is being seen as important grey areas to address sector barriers and challenges by the policy makers. This research study also found very relevant to IT policy development so that priority based investments can be made on the grey sectors in near future. Hence, study is useful for making efforts for policy initiatives related to e-Governance implementation and also to support India as the emerging Digitalized nation.

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Figures

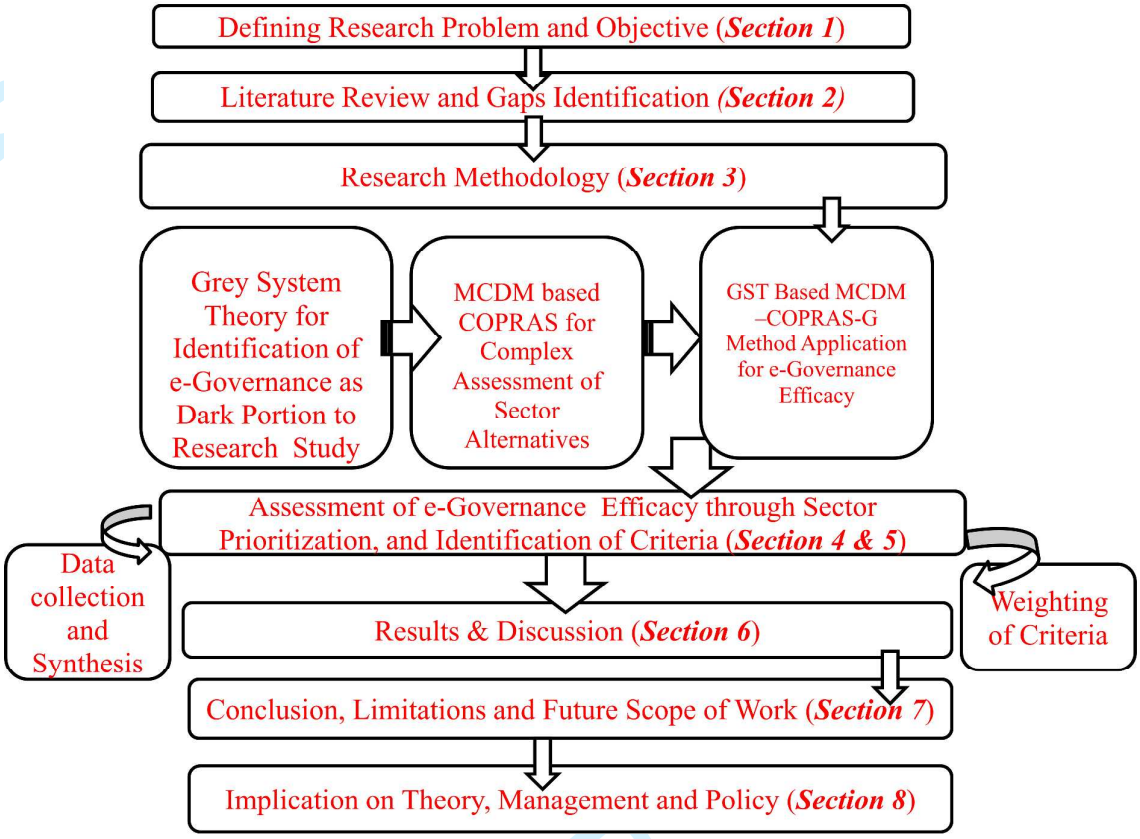

Figure 1: Research Design Flow

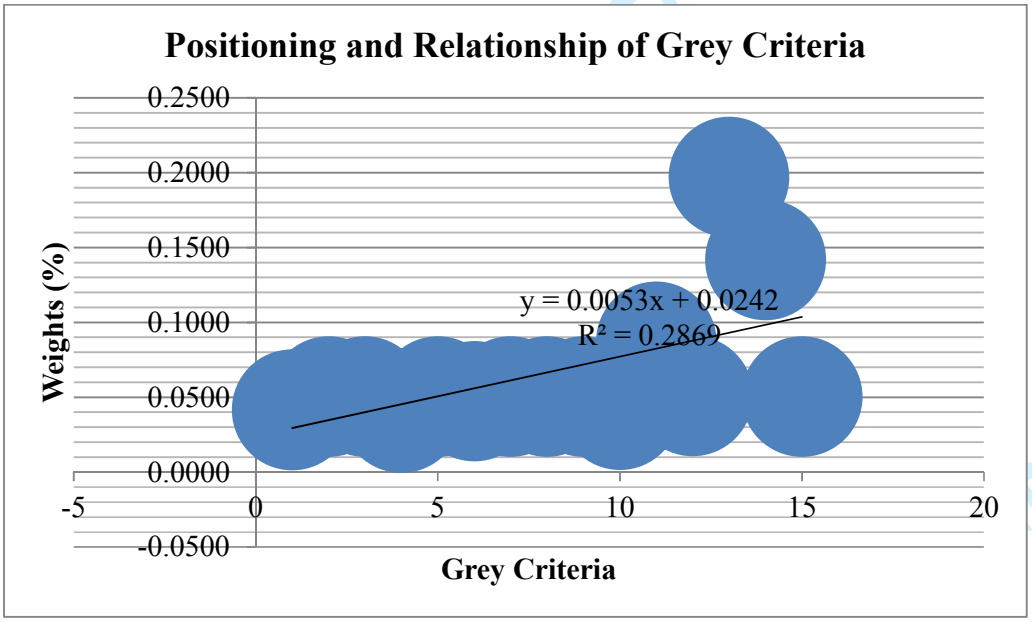

Figure 2: Weights of Various Criteria

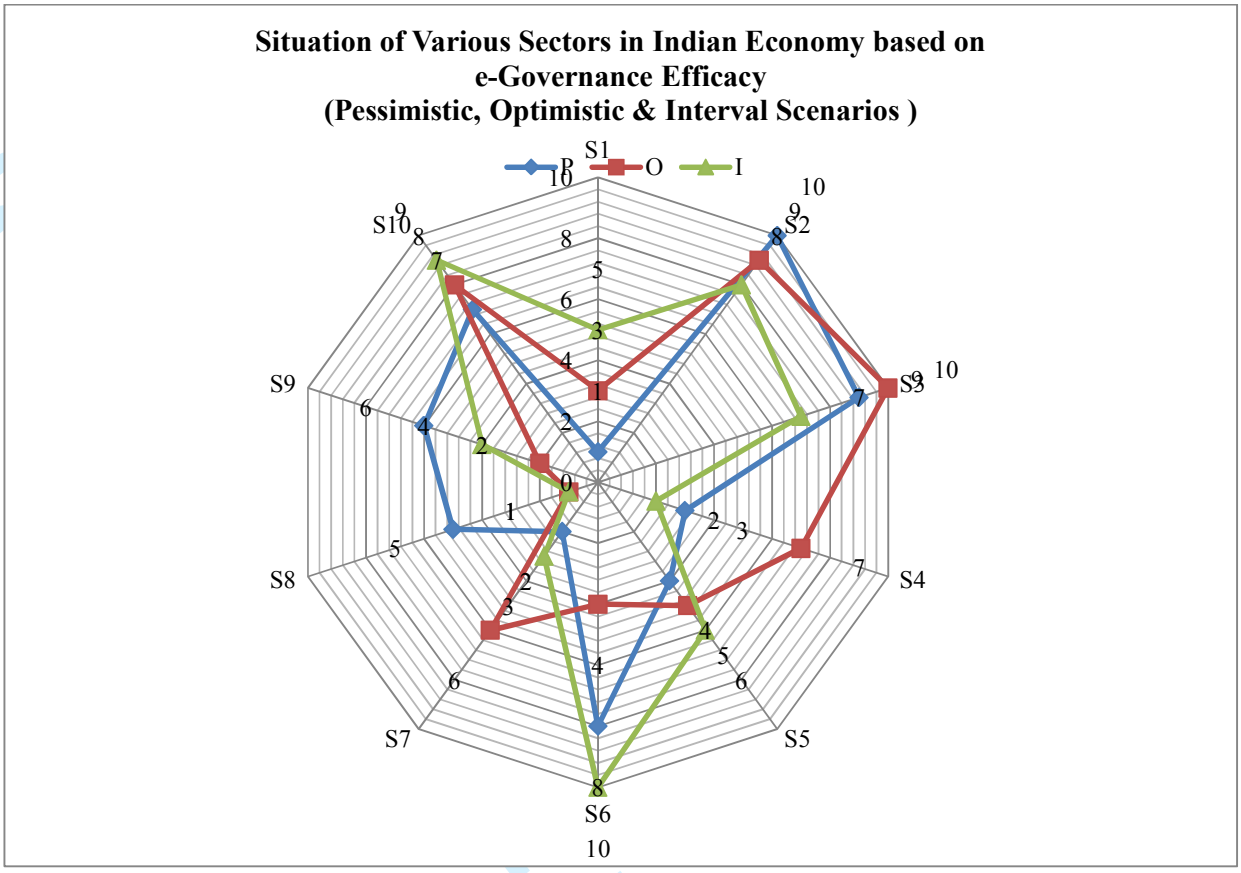

Figure 3: Sectors in Indian Economy based on e-Governance Efficacy

Tables

Sr. No.	***Papers description***	***References***
1.	Public administration and public affairs	Henry (1989)
2.	Electronic service delivery in public administration	Bekkers and Zouridis (1999)
3.	Insider cyber-threats	Hamin (2000)
4.	Towards an information architecture for public administration	Peristeras and Tarabanis (2000)
5.	Computer crimes	Dhillon & Moores (2001)
6.	e-Government in the Asia-Pacific Region	Wescott (2001)
7.	Violation of safeguards	Dhillon (2001)
8.	Analyzing the past to prepare for the future	Webster and Watson (2002)
9.	Economics of investment in information security	Gordon and Loeb (2002)
10.	Threat prediction tool	Magklaras and Furnell (2002)
11.	The e-Government imperative	Attal (2002)
12.	e-Government and e-Governance	Marche and McNiven (2003)
13.	Sustainable fishing development strategies	Chiou and Cheng (2005)
14.	Evaluative design of e-government projects	Grimsley *et al.* (2007)
15.	Threat management	Steele and Wargo (2007)
16.	Fuzzy simulation in healthcare organizations	Khoumbati and Themistocleous (2007)
17.	An online social network for emergency management	White *et al.* (2009)
18.	Human factors in information security	Colwill (2009)
19.	Addressing bad actors and their actions	Pfleeger (2010)
20.	Citizen participation and involvement in e-government	Axelsson *et al.* (2010)
21.	Trend of the security research	Hong *et al.* (2010)
22.	Best practices on Finnish Government Policy	Inkinen, (2012)
23.	Common sense to insider threats	Silowash *et al.* (2012)
24.	Cyberterrorism	Harries and Yellowlees (2012)
25.	Promoting transparency and accountability through ICTs	Bertot *et al.* (2012)
26.	RTI Act: A tool for good governance through ICT	Singh and Karn (2012)
27.	The evidence of e-government procurement	Rotchanakitumnuai (2013)
28.	Transforming local government: A project portfolio	Hansen and Kræmmergaard (2013)
29.	A fuzzy rule-based system to assess e-government technical interoperability maturity	Corrêa *et al.* (2014)
30.	ICT enabled participatory urban planning	Khan *et al.* (2014)
31.	Transforming government	Zahir and Muhammad (2014)
32.	Demographic factors as determinants of e-governance adoption: A field study in UAE	Aldin *et al.(*2015)
33.	E-government in labor and social security regulation	Stefanou and Skouras (2015)
34.	A strategic framework for good governance	Kalsi and Kiran (2015)
35.	Strategic relationship between information quality and e-government benefits	Alenezi *et al.* (2015)
36.	Measuring public value of e-governance	Gupta and Suri (2017)
37.	IT assets , infrastructure performance & capability	Dhaiya and Mathew (2016)

Table I: Important Literature on Information Security, Threats, e- Governance: Management and Administration Perspectives

Grey Criterion (Cj)	***Description of grey criterion***	***Criterion type/ Optimization orientation***	***References***
⊗ *C1*	IT –Infrastructure availability (Digital electronic network: Suitability and readiness for e-Governance in Pre-liberalization)	Qn. / Max.	Infrastructure Development in India Reforms, Ahluwalia M.S. Planning Commission, GoI; Second ARC Report,(2008)
⊗ *C2*	IT –Infrastructure availability (Digital electronic network: Suitability and robustness for e-Governance in Post- liberalization)	Qn. / Max.	
⊗ *C3*	Ability to IT –Policy adoption (Pre-liberalization)	Ql. / Max.	Five Year Plan 2012-17, GoI and National Telecom Policy (2012), Deity, GoI
⊗ *C4*	Ability to IT –Policy adoption (Post-liberalization)	Ql. / Max.	
⊗ *C5*	Degree of cyber threats and vulnerability impacting sector services and compliance of security standard practices	Ql./ Min.	Cyber situational awareness –A systematic review of literature: Franke and Brynielsson, (2014) A security standards' framework to facilitate best practices' awareness and conformity: Tsohou *et.al.*, (2010)
⊗ *C6*	Amount of investment in the sector for sustainable development	Qn./ Min.	Consolidated Foreign Direct Investment Policy,(2016), DIPP, GoI
⊗ C7	IT initiatives impact on supply chain performance of e-commerce market	Qn. / Max.	Sindhuja (2014)
⊗ *C8*	Ability of digital network in service delivery of central sector schemes (CSS)	Ql. / Max.	Website of NITI Aayog, GoI
⊗ *C9*	Sector ability to increase literacy rate and environmental education mandate	Ql. / Max.	Yacine and Marks (2008); Education Policy and National Digital Literacy Mission, GoI (2016)
⊗ *C10*	Support for ease of doing business	Ql. / Max.	Bonham *et al.*, (2003); RBI Report of the working group to revisiting priority sector lending, 2015; And National strategy on information security, Information security policy council, (2016)
⊗ *C11*	Political interference and efforts to initiate concept of e-Cabinet	Ql. / Min.	
⊗ *C12*	IT-professional strength, capacity building (change management)	Ql. and Qn. / Max.	
⊗ *C13*	Support employment rate	Qn. / Max.	
⊗ *C14*	Sector support to economic growth	Qn. / Max.	
⊗ *C15*	Severity of national security threats	Ql./ Min.	

Table II (a): Criteria for e-Governance Efficacy Assessment using COPRAS-G Method
(*Source: Criteria identified from feedback from training programmes under Digital India Programme*)

Criterion (Cj)	*Description of criterion*
C1	IT –Infrastructure availability (in Pre-liberalization)
C2	IT –Infrastructure availability (in Post- liberalization)
C3	Ability to IT –Policy adoption (Pre-liberalization)
C4	Ability to IT –Policy adoption (Post-liberalization)
C5	Degree of cyber threats and vulnerability impacting sector services and compliance of security standard practices
C6	Amount of investment in the sector for sustainable development
C7	IT initiatives impact on supply chain performance of e-commerce market
C8	Ability of digital network in service delivery of central sector schemes (CSS)
C9	Sector ability to increase literacy rate and environmental education mandate
C10	Support for ease of doing business
C11	Political interference and efforts to initiate concept of e-Cabinet
C12	IT-professional strength, capacity building (change management)
C13	Support employment rate
C14	Sector support to economic growth
C15	Severity of national security threats

Table II (b): Select List of Grey Criteria and Their Description for COPRAS-G Applications

(*Source: Criteria identified from feedback from training programmes under Digital India Programme*)

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Linguistic Scale (6-Point)	Triangular Fuzzy Numbers (TFNs in the form of n, a, b)	m	a	b	Magnitude of TFN (Yager Index)
Just Equal (JE)	(1, 1, 1)	1	1	1	1.00
Equally important (EI)	(1, 1, 3)	1	1	3	1.67
Weakly important (WI)	(1, 1, 5)	1	1	5	2.33
Strongly important (SI)	(3, 5, 7)	3	5	7	3.67
Very strongly important (VSI)	(5, 7, 9)	5	7	9	5.67
Extremely preferred (EP)	(7, 9, 9)	7	9	9	7.00

Table III: Linguistic Scale of Triangular Fuzzy numbers (TFNs) and their Modulus (YI)

Cj×*Cj*	⊗C1	⊗C2	⊗C3	⊗C4	⊗C5	⊗C6	⊗C7	⊗C8	⊗C9	⊗C10	⊗C11	⊗C12	⊗C13	⊗C14	⊗C15
⊗C1	(1, 1, 1)	(1, 1, 3)	(1, 1, 3)	(1, 1, 3)	(1, 1, 3)	(1, 1, 5)	(7, 9, 9)	(3, 5, 7)	(7, 9, 9)	(1, 1, 5)	(1, 1, 5)	(7, 9, 9)	(3, 5, 7)	(1, 1, 3)	(3, 5, 7)
⊗C2	(1/3, 1,1)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)
⊗C3	(1/3, 1,1)	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)	(7, 9, 9)	(1, 1, 3)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)	(7, 9, 9)	(5, 7, 9)	(1, 1, 3)	(3, 5, 7)
⊗C4	(1/3, 1,1)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1, 1, 1)	(1, 1, 3)	(1, 1, 5)	(3, 5, 7)	(1, 1, 3)	(1, 1, 5)	(1, 1, 5)	(1, 1, 3)	(7, 9, 9)	(3, 5, 7)	(1, 1, 3)	(3, 5, 7)
⊗C5	(1/3, 1,1)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1/3, 1,1)	(1, 1, 1)	(1, 1, 3)	(3, 5, 7)	(1, 1, 5)	(1, 1, 3)	(1, 1, 3)	(1, 1, 5)	(7, 9, 9)	(3, 5, 7)	(1, 1, 3)	(3, 5, 7)
⊗C6	(1/5, 1, 1)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1/5, 1, 1)	(1/3, 1,1)	(1, 1, 1)	(3, 5, 7)	(1, 1, 3)	(1, 1, 3)	(1, 1, 3)	(1, 1, 3)	(7, 9, 9)	(3, 5, 7)	(1, 1, 3)	(5, 7, 9)
⊗C7	(1/9, 1/9, 1/7)	(1/7, 1/5, 1/3)	(1/9, 1/9, 1/7)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)
⊗C8	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/3, 1,1)	(1/3, 1,1)	(1/5, 1, 1)	(1/3, 1,1)	(1/5, 1, 1)	(1, 1, 1)	(1, 1, 3)	(1, 1, 5)	(3, 5, 7)	(7, 9, 9)	(7, 9, 9)	(1, 1, 3)	(1, 1, 5)
⊗C9	(1/9, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1/5, 1, 1)	(1/5, 1, 1)	(1/3, 1,1)	(1/3, 1,1)	(1/5, 1, 1)	(1/3, 1,1)	(1, 1, 1)	(1, 1, 5)	(1, 1, 3)	(5, 7, 9)	(1, 1, 3)	(3, 5, 7)	(3, 5, 7)
⊗C10	(1/5, 1, 1)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1/5, 1, 1)	(1/3, 1,1)	(1/3, 1,1)	(1/5, 1, 1)	(1/5, 1, 1)	(1/5, 1, 1)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(7, 9, 9)	(5, 7, 9)
⊗C11	(1/5, 1, 1)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1/3, 1,1)	(1/5, 1, 1)	(1/3, 1,1)	(1/5, 1, 1)	(1/7, 1/5, 1/3)	(1/3, 1,1)	(1/7, 1/5, 1/3)	(1, 1, 1)	(7, 9, 9)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)
⊗C12	(1/9, 1/9, 1/7)	(1/7, 1/5, 1/3)	(1/9, 1/9, 1/7)	(1/9, 1/9, 1/7)	(1/9, 1/9, 1/7)	(1/9, 1/9, 1/7)	(1/5, 1, 1)	(1/9, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1/9, 1/9, 1/7)	(1, 1, 1)	(1, 1, 5)	(1, 1, 5)	(1, 1, 5)
⊗C13	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1/9, 1/9, 1/7)	(1/3, 1,1)	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)	(1/5, 1, 1)	(1, 1, 1)	(1, 1, 5)	(1, 1, 5)
⊗C14	(1/3, 1,1)	(1/7, 1/5, 1/3)	(1/3, 1,1)	(1/3, 1,1)	(1/3, 1,1)	(1/3, 1,1)	(1/5, 1, 1)	(1/3, 1,1)	(1/7, 1/5, 1/3)	(1/9, 1/9, 1/7)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1/5, 1, 1)	(1, 1, 1)	(1, 1, 3)
⊗C15	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)	(1/5, 1, 1)	(1/5, 1, 1)	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1/5, 1, 1)	(1/5, 1, 1)	(1/3, 1,1)	(1, 1, 1)

Table IV: Decision Matrix 'M' for Assignment of Relative Importance to Criteria Vs Criteria

Sector Alternative (Sj)	*Sum of Maximizing Criteria*	*Sum of Minimizing Criteria*	*Reciprocal of Rj*	*Relative Significance*	*Performance (Utility Degree)*	*Sector-Alternative Rank*
	Mj	*Rj*	*1/Rj*	*Qj = (Rj +1/Rj)*	*Nj (%)*	
S1 (Agriculture)	0.086	0.016	62.424	0.118	100.0%	1
S2 (Aerospace)	0.056	0.021	47.107	0.079	67.4%	10
S3 (Defense)	0.063	0.020	49.012	0.088	74.9%	9
S4 (Education)	0.078	0.015	65.200	0.111	94.1%	3
S5 (Finance)	0.079	0.019	53.963	0.106	90.3%	4
S6 (Environment & Climate Change)	0.072	0.029	34.101	0.089	75.6%	8
S7 (Health)	0.090	0.023	42.964	0.111	94.4%	2
S8 (Industrial)	0.091	0.035	28.453	0.106	89.6%	5
S9 (International Cooperation)	0.087	0.037	27.062	0.100	85.1%	6
S10 (Railways)	0.063	0.019	53.141	0.090	76.5%	7
Max., Min. values of (S*j*), (R*j*)	0.086	0.015		Max. (*Qj*) = 0.03306	Optimality Criterion (*K*) =Max. (Q*j*)	
Sum	0.765	0.24	463.426			

Table V: Pessimistic Scenario of Sector Prioritization to Assess e-Governance Efficacy

Sector Alternative (Sj)	*Sum of Maximizing Criteria*	*Sum of Minimizing Criteria*	*Reciprocal of Rj*	*Relative Significance*	*Performance (Utility Degree)*	*Sector-Alternative Rank*
	Mj	*Rj*	*1/Rj*	*Qj = (Rj +1/Rj)*	*Nj (%)*	
S1 (Agriculture)	0.081	0.018	56.462	0.081	89.3%	3
S2 (Aerospace)	0.065	0.021	47.405	0.065	71.5%	9
S3 (Defense)	0.064	0.021	48.020	0.064	70.7%	10
S4 (Education)	0.074	0.016	63.295	0.074	82.0%	7
S5 (Finance)	0.076	0.020	50.445	0.076	83.8%	5
S6 (Environment & Climate Change)	0.080	0.030	33.190	0.080	88.7%	4
S7 (Health)	0.075	0.024	41.312	0.075	82.4%	6
S8 (Industrial)	0.090	0.031	31.984	0.090	100.0%	1
S9 (International Cooperation)	0.086	0.033	30.141	0.087	95.6%	2
S10 (Railways)	0.074	0.021	47.611	0.074	81.6%	8
Max., Min. values of (S*j*), (R*j*)	0.090	0.02		Max. (Qj) = 0.090	Optimality Criterion (*K*) =Max. (Q*j*)	
Sum	0.76	0.24	449.86			

Table VI: Optimistic Scenario of Sector Prioritization to Assess e-Governance Efficacy

Sector Alternative (Sj)	*Sum of Maximizing Criteria*	*Sum of Minimizing Criteria*	*Reciprocal of Rj*	*Relative Significance*	*Performance (Utility Degree)*	*Sector-Alternative Rank*
	Mj	*Rj*	*1/Rj*	*Qj = (Rj +1/Rj)*	*Nj (%)*	
S1 (Agriculture)	0.042	0.011	87.490	0.058	92.6%	5
S2 (Aerospace)	0.042	0.014	71.866	0.056	88.1%	8
S3 (Defense)	0.044	0.014	71.866	0.057	90.0%	7
S4 (Education)	0.045	0.011	93.624	0.062	99.1%	2
S5 (Finance)	0.043	0.013	78.900	0.057	90.5%	6
S6 (Environment & Climate Change)	0.041	0.016	60.977	0.052	82.1%	10
S7 (Health)	0.047	0.014	69.395	0.060	95.3%	3
S8 (Industrial)	0.052	0.017	59.201	0.063	100.0%	1
S9 (International Cooperation)	0.050	0.018	55.140	0.060	95.1%	4
S10 (Railways)	0.036	0.009	105.885	0.055	87.4%	9
Max., Min. values of (S*j*), (R*j*)	0.052	0.011		Max. (Q*j*) = 0.0630	Optimality Criterion (*K*) =Max. (Q*j*)	
Sum	0.442	0.14	754.34			

Table VII: Realistic (Interval) Scenario of Sector Prioritization to Assess e-Governance Efficacy

Sector-Alternative Priority Order		**Sector Rank obtained from the COPRAS-G Methodology in Various Scenario (s)**		
	Sector Code	***Pessimistic***	***Optimistic***	***Interval or Realistic***
Agriculture	S1	1	3	5
Aerospace	S2	10	9	8
Defense	S3	9	10	7
Education	S4	3	7	2
Finance	S5	4	5	6
Environment	S6	8	4	10
Social & Health	S7	2	6	3
Industrial	S8	5	1	1
International Cooperation	S9	6	2	4
Railways	S10	7	8	9

Table VIII: Sector Scenarios highlighting their Differences and Comparison

Appendix-A & B

Appendix-A

Various Equations used in COPRAS & COPRAS-G Methods

$$\tilde{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad \text{Equation (1)}$$

Where, (x_{ij}) is the performance of the i-th alternative with respect to the j-th criterion, and ($\tilde{x}_{ij}$) is it's normalized value and (m) is the number of alternatives.

$$C_{+i} = \sum_{j=1}^{k} \tilde{x}_{ij} \cdot q_i \quad \text{Equation (2)}$$

$$C_{-i} = \sum_{j=k+1}^{n} \tilde{x}_{ij} \cdot q_i \quad \text{Equation (3)}$$

Where, (k) is number of maximizing criteria; (n) is total number of criteria; and (q_i) is significance of the i-th criterion**.**

$$Q_i = C_{+i} + \frac{\min_i C_{-i} \sum_{i=1}^{m} C_{-i}}{C_{-i} \sum_{i=1}^{m} \frac{\min_i C_{-i}}{C_{-i}}} \quad \text{Equation (4)}$$

$$Q_i = C_{+i} + \frac{\sum_{i=1}^{m} C_{-i}}{C_{-i} \sum_{i=1}^{m} \frac{1}{C_{-i}}} \quad \text{Equation (5)}$$

$$P^* = \left\{ P_i \middle| \max_i Q_i \right\} \quad \text{Equation (6)}$$

$$\underline{\tilde{x}}_{ij} = \frac{\underline{x}_{ij}}{\frac{1}{2}\left(\sum_{i=1}^{m} \underline{x}_{ij} + \sum_{i=1}^{m} \bar{x}_{ij} \right)} = \frac{2\underline{x}_{ij}}{\sum_{i=1}^{m} \underline{x}_{ij} + \sum_{i=1}^{m} \bar{x}_{ij}} \quad \text{Equation (7)}$$

$$\bar{\tilde{x}}_{ij} = \frac{\bar{x}_{ij}}{\frac{1}{2}\left(\sum_{i=1}^{m} \underline{x}_{ij} + \sum_{i=1}^{m} \bar{x}_{ij} \right)} = \frac{2\bar{x}_{ij}}{\sum_{i=1}^{m} (\underline{x}_{ij} + \bar{x}_{ij})} \quad \text{Equation (8)}$$

In equations (7) and (8), $\underline{x}_{ij}$ and $\bar{x}_{ij}$ are the lowest and highest performance of the i-th alternative with respect to the i-th criteria whereas $\widetilde{\underline{x}}_{ij}$ and $\widetilde{\bar{x}}_{ij}$ are its normalized values.

$$C_{+i} = \frac{1}{2}\sum_{j=1}^{k}(\widetilde{\underline{x}}_{ij} + \widetilde{\bar{x}}_{ij}) \cdot q_i \qquad \text{Equation (9)}$$

And, the sum of minimizing criteria $C_{-i.}$ is given by

$$C_{-i} = \frac{1}{2}\sum_{j=k+1}^{n}(\widetilde{\underline{x}}_{ij} + \widetilde{\bar{x}}_{ij}) \cdot q_i \qquad \text{Equation (10)}$$

$$X = \begin{bmatrix} x_{11} & \cdots & [\underline{x}_{1j}, \bar{x}_{1j}] & \cdots & x_{1n} \\ x_{21} & \cdots & [\underline{x}_{2j}, \bar{x}_{2j}] & \cdots & x_{2n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{m1} & \cdots & [\underline{x}_{mj}, \bar{x}_{mj}] & \cdots & x_{mn} \end{bmatrix} \qquad \text{Equation (11)}$$

Where, (x_{ij}) *is performance* of i-th *alternative* with respect to j-th criterion, m is number of alternatives and (n) is number of criteria. For criteria which performance is determined in intervals (x_{ij}), it is determined by its lower limit $\underline{x}_{ij}$ and the upper limit $\bar{x}_{ij}$.

$$C_{+i} = C_{+i}^{c} + C_{+i}^{g}. \qquad \text{Equation (12)}$$

In the formula (12), C_{+i}^{c} is the sum of maximizing criteria with crisp values of i-th alternative, calculated using formula (2), and C_{+i}^{g} is the sum of maximizing criteria with values are expressed in intervals, calculated using formula (9).

$$C_{-i} = C_{-i}^{c} + C_{-i}^{g} \qquad \text{Equation (13)}$$

In the formula (13), the sums of minimizing criteria with crisp values C_{-i}^{c} are calculated using formula (9) and sums of minimizing criteria with values expressed in intervals C_{-i}^{g} using formula (10).

$$(x) = (m, a, b)_{LR} \qquad \text{Equation (14)}$$

$$\tilde{T}_1 \oplus \tilde{T}_2 = (l_1 + l_2,\ m_1 + m_2,\ u_1 + u_2) \qquad \text{Equation (15)}$$

$$\tilde{T}_1 \otimes \tilde{T}_2 = (l_1 \times l_2,\ m_1 \times m_2,\ u_1 \times u_2) \qquad \text{Equation (16)}$$

$$r \otimes \tilde{T}_1 \cong (rl_1,\ rm_1,\ ru_1) \quad \text{Equation (17)}$$

$$\tilde{T}1^{-1} \cong (1/l_1,\ 1/m_1,\ 1/u_1) \quad \text{Equation (18)}$$

$$\text{Yager Index, } F\ (m, a, b) = \left(\frac{3m-a+b}{3}\right) \quad \text{Equation (19)}$$

Appendix-B

Procedure for Criteria Weighting

If the object set is represented as $X = \{x_1, x_2, \ldots, x_n\}$ and the goal set as, G= {g_1, g_2..., g_m}, then according to the concept of extent analysis (Chang 1991, 1996), each object is taken and extent analysis for each goal G_i is performed respectively. The *m* extent analysis values for each object are denoted as:

$$M_{gi}^{1}, M_{gi}^{2}, \ldots, M_{gi}^{m}$$, Where, i=1, 2,..., n.

Where, all the, $M_{gi}^{j}\ (j = 1, 2, \ldots..m)$ are triangular fuzzy numbers. M_{gi}^{m} Represents the value of the extent analysis of the i^{th} object for m^{th} goal. Therefore, the value of fuzzy synthetic extent with respect to the i^{th} goal is defined by the following equation.

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$$

Where, S_i gives the synthetic values and the value of $\sum_{j=1}^{m} M_{gi}^{j}$ can be estimated by performing the fuzzy addition operation of *m* extent analysis values from a particular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} n_{1j}, \sum_{j=1}^{m} n_{2j}, \sum_{j=1}^{m} n_{3j}\right)$$

And the value of $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]$ can be obtained by performing the fuzzy addition operation of $M_{gi}^{j}\ (j = 1, 2, \ldots..m)$ such that:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} n_{1j}, \sum_{i=1}^{n} n_{2j} \sum_{i=1}^{n} n_{3j}\right)$$

Further, in addition to above, $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ can be calculated by the inverse of the previous equation as follows:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} n_{3i}}, \frac{1}{\sum_{i=1}^{n} n_{2i}}, \frac{1}{\sum_{i=1}^{n} n_{1i}}\right)$$

The degree of possibility of $M_1 = (l_1, m_1, u1) \geq M_2 = (l_2, m_2, u_2)$ is defined as:

$$V(M_1 \geq M_2) = \sup_{x \geq y}\left[\min(\mu_{M_1}(x), \mu_{M_2}(y))\right]$$

When a pair (x, y) exists such that $x \geq y$, *and* $\mu_{M_1}(x) = \mu_{M_2}(y) = 1$, then V $(M_1 \geq M_2) = 1$.

Where, *l, m, u* notations represents lower, middle and upper value of M_i. *and s*ince, *M1* and M_2 are convex fuzzy numbers such that, $V(M_1 \geq M_2) = 1$ if $m_1 \geq m_2$, and $V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M1}(d)$, where d is the ordinate of the highest intersection point D between μ_{M_1} μ_{M_2}. And further the values of $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ then ordinate of (D) is computed as follows.

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}$$

For the comparison of $M_1$and M_2, both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ are required. The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i= 1, 2,….., k) can be defined by,

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) and (M \geq M_2) \ldots and (M \geq M_k)]$$

$$= min\ V(M \geq M_i), \quad i=1, 2, \ldots, k$$

Here, *min* represents minimum value, and *P* indicates possibility. If *min* $(p_i) = minV(S_i \geq S_k)$, For k=1, 2,….. , *n,* $k \neq i$. then the weight vector is given by,

$$W_p = (\min(p_1), \min(p_2), \ldots, \min(p_n))^T,$$

Where, W_p, is the weights among possibilities of minimum values, and Pi (i = 1, 2,….. , n) are n elements. After normalizing W_p, we get the normalized weight vectors such that

$$W = (w(p_1), w(p_2), \ldots, w(p_n))^T,$$

Where, W is a non-fuzzy number and this gives the priority weights of one alternative over other.