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Research on e-Government evaluation model based on the principal component analysis

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Abstract Over the last few years, the area of electronic government (e-Government) has received increasing prominence and attention; people are interacting with e-Government systems to an ever greater extent. It is therefore important to measure the development of e-Government. Adopting principal component analysis (PCA), this study presents, validates and updates an evaluation model with 5 dimensions based on Socio-Technical model and Stakeholder Theory, which captures the multidimensional and interdependent nature of e-Government system. The validity of the model is empirically investigated using a sample of local e-Government of 18 cities in China, all of which have high Internet penetration and mature ICT use. The five dimensions of the evaluation model include project construction, information security management, special construction, transparency of government affairs and informationized ability. K-means clustering is applied in the subspace created by PCA to evaluate the local e-Government stages of growth of these 18 cities. The findings provide several important implications for e-Government research and practice.

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1 Introduction

The emergence of digital economy and the proliferation of the Internet and World Wide Web applications, characterized by the widespread use of the Internet and e-Business, have exerted a significant effect on business models all over the world. In addition to business models, the administrative models of governments have been affected by the advent of internet age as well. As Internet technology became more readily available, the reformulation of productive processes and the reengineering of business processes in every arena became a reality. With particular respect to governments, they have been involved more and more in what is now known as electronic government projects (e-Government) to strive for greater efficiency, effectiveness, and accountability in their relationship with their stakeholders [15, 31].

Since the late 1990s, governments at all levels have launched e-Government projects aimed at providing electronic information and services to citizens and businesses [58]. With a growing realization of the value of using information and communication technologies (ICTs), an increasing number of governmental units are incorporating or expanding the use of ICTs into many of their activities to provide efficient and transparent government [46].

E-Government is the transformation of public sector internal and external relationships through net-enabled operations, information technology and communications, to optimize government service delivery, constituency participation and governance [2]. It can be broadly defined as a government's use of ICT, particularly Web-based Internet applications, to enhance the access to and the delivery of government information and service to stakeholders such as citizens, business partners, public sector employees, and other governments, agencies and entities. It can change the relationship between governments and the various stakeholders mentioned above from hierarchical command-and-control to interactive collaboration [36, 47, 68].

E-Government provides a platform for multi-channel interaction and multi-service delivery options. It can have an influence on cultural and social adaptation issues, trans-border data flow issues, and it can raise the potential for the development of a policy to reduce the global digital divide. Therefore, the construction and management of e-Government systems are becoming an essential element of modern public administration [56, 58].

Given their decisive role, e-Government projects can absorb a significant amount of public funds. Hence, it is very important to analyze its feasibility and access its performance. It is also essential that such a major undertaking should undergo post-implementations assessment. Based on the results of the assessment, government could take necessary and corresponding actions. Such evaluation efforts can enable government agencies to ascertain whether they are capable of doing the required task and delivering services as expected [16].

However, little is known about the quality and efficiency of e-Government initiatives, partially because of a lack of effective measures to evaluate e-Government quality [4]. Heeks [18] reports that failure rates of e-Government projects are estimated to be as high as 85%. A more recent study conducted by Sauer and Cuthbertson reported that only 16% of Information Technology (IT) projects were considered successful [49]. Due to the high failure rates, more and more attention from all over the world has been paid to the area of e-Government over the last few years to improve its performance. Both the diversity of topics and the volume of articles dealing with e-Government have increased [14]. Many e-Government studies focus on the development and evaluation of a Web site that interfaces between a government and its citizens [6, 8, 11, 50]. Yet researchers who concentrate on e-Government as technology-led solutions often miss out the context and nuances of governance which make e-Government meaningful in the final analysis [59, 60].

As we discussed above, evaluating the development of e-Government projects is an important issue. The lack of recognized methods for monitoring and assessing e-Government initiatives has led to a significant slowdown of country-level e-Government development [30, 32–34]. Furthermore, an e-Government project may involve a country, a region or a city; evaluations can therefore differ in their level and unit of analysis. It is necessary to differentiate between national and local e-Government models because they have different goals, objectives, and constraints [53, 61]. In reality, however, current research in the e-Government area focuses mainly on the national level and significantly less has been available with reference to local governments, which does, in fact, have a great impact on citizens and their daily lives, because they have the most direct contact with the citizens and businesses and are responsible for providing an array of basic services.

As there is a shortage of usable theories and models for e-Government at the local level, we do not have adequate knowledge about e-Government initiatives and practices at the local level. Some researchers put forward that the research directions should concerned with local e-Government [35]. This study assesses e-Government projects at the level of local government in China. Specially, it assesses the status of local e-Government of the main coastal cities in the east of China and several major cities in the inland of China, all of which have high Internet penetration and mature ICT use.

This paper aims at proposing and testing the integrated model to enhance and improve both the understanding and knowledge of e-Government evaluation in practice and exploring the phenomenon of local e-Government projects in China. The remainder of the paper is organized as follows. A brief introduction of the system of local governments in China will be first given in Sect. 2, followed by a literature review of e-Government evaluation in Sect. 3. Next in Sect. 4 the research model and methodology of the present study is presented, and finally research results are provided and discussed in Sect. 5.

2 The Chinese system of local government

The government system of China is mainly distributed across two layers: the central government and the local government. In order to conduct effective administration in such a geographically stretched and densely populated country, both of these two layers are further divided into several units to address the multitude of government responsibilities. The local governments have the greatest direct contact with citizens.

Presently the local government of China is basically divided into four categories: municipalities, provinces, autonomous regions and special administrative regions. The municipalities include Beijing, Tianjin, Shanghai and Chongqing. As we know, Beijing is the capital of China, a center of politics, culture and international exchange. Shanghai is an international metropolis, an important economic and trading center of the world. China has 23 provinces, each of which has its own provincial government. There are five autonomous regions and two special administrative regions in China, all of which have their own government as well. Local governments at all levels in China make use of the responsibility system of governors, mayors and lower level governors. The responsibility system implemented in local governments of China motivates local governments to launch reform programs with the aim of improving the quality of service as well as the availability of service to citizens and businesses.

3 Literature review

3.1 Theoretical foundation

The most essential theoretical basis for our research model is the socio-technical model [3]. The socio-technical model (STM) incorporates four interdependent social and technical elements: actors, structure, technology, and task. The socio-technical model examines key design elements for information systems. The STM states that information system failures can be reduced by considering two complementary system components: the social side (focusing on user attitudes, skills, and values) and the technical side (focusing on processes, tasks, and technology). Social systems consist of people and structures while technical systems consist of technology and tasks. These four constructs are all interrelated (see Fig. 1).

The socio-technical perspective envisions humans and technology in supporting rather than antagonistic roles. The STM is applicable in e-Government because of the interplay between people and technology. The social context is important and a more integrated social-technical view is interesting in order to avoid the separation of social behaviors from technologies [24, 28].

For some nations, e-Government merely means shifting current services online, whereas to others, e-Government presents new exciting opportunities to restore relations between government and citizens and to boost public participation in the process of democracy [54]. E-Government projects involve a wide range of services, products, people, and procedures. Lots of researchers have argued for a new vision of e-Government, taking into account the perspective of not only the suppliers but also other key stakeholders such as citizens [1, 21, 37, 43]. This is based on another theoretical basis of this research, i.e. the Stakeholder Theory, which was first put forward by Donaldson and Preston [10]. A stakeholder represents any entity such as individual, group, and firm that can affect or be affected by the organization's execution of its objectives [45]. A key distinction can be drawn between the tenets of the Stakeholder Theory and the conventional input–output model of the firm which see firms as converting investor, supplier, and employee inputs into customer outputs [10]. In contrast, the Stakeholder Theory argues that every legitimate person or group participating in the activities of a firm does so to obtain benefits and that the priority of the interests of all legitimate stakeholders is not self-evident (see Fig. 2). Stakeholders are identified by their interests and all stakeholder interests are considered to be intrinsically valuable. So, in order to guarantee the sustainable development of enterprises, companies should be responsible for their stakeholders, and take both internal and external rights and interests into account in the process of governance.

The Stakeholder Theory is managerial in that it recommends attitudes, structures, and practices and requires that simultaneous attention be given to the interests of all legitimate stakeholders. Lots of previous studies were based on it. Some researchers used this theory to investigate the evolution of E-commerce research from the stakeholder perspective [5]. Other researchers adopted the Stakeholder Theory and stakeholder analysis approach to e-Government in order to investigate stakeholder governance, to implement strategies for e-Government and to explore stakeholders' expectations of the benefits and barriers of e-Government knowledge sharing [9, 13, 51, 67].

In light of the Stakeholder Theory introduced above, we can propose that the primary stakeholders interested in e-Government projects of China include:

- Citizens: Citizens in contact with public administration, using public services exercising their civil rights, and participating in democratic processes.

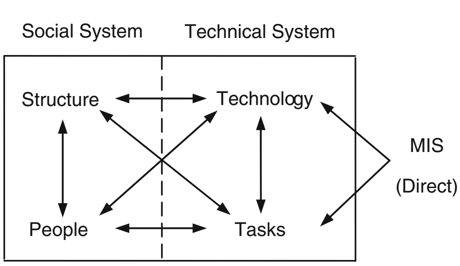

Fig. 1 Socio-technical model

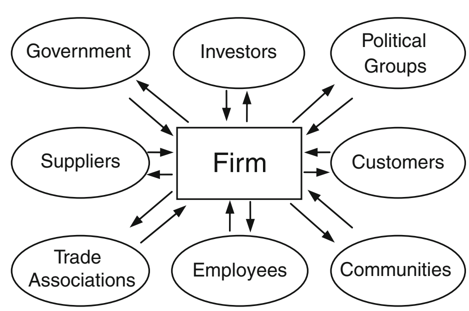

Fig. 2 Donaldson and Preston's stakeholder theory

- Businesses: Both for-profit and non-profit companies interact with government. Businesses are in contact with public administration in their compliance with taxes, social, and legal obligations.
- Employees: All categories of public employees, including politicians, civil servant and various other public administrators.
- Governments: In multi-level systems, there is interaction among local, provincial, and national level governments.

There are four general types of e-Government systems and services: government to citizen (G2C), government to businesses (G2B); government to government (G2G) and government to employee (G2E). Though both businesses and governments can no doubt benefit from e-Government, citizens are the ones that receive the widest array of benefits from e-Government [25]. G2E is called the effectiveness of internal efficiency e-Government model alternatively. The launch of G2E indicates that government has realized internal e-administration, which constitutes the basis of G2C, G2B, G2G [64, 65].

In addition, a lot of studies used Delone and Mclean's IS success model to evaluate the success of information systems [23, 39, 48], measuring e-commerce success [7, 40, 52], KMS success [29, 66], and other IS success [20, 42, 55], including the success of G2C e-Government [63]. But this model is proposed from subjective point, and it focus on desires and motives.

3.2 Assessment of e-Government initiatives

Evaluation of e-Government projects identifies strengths, weaknesses, and the best practices for both local and international integration [30]. The European Union offers eEurope Awards on the basis of three evaluation criteria: innovativeness and effective management; practical results; and relevance and transferability. The implications of such awards highlight the importance of setting standards and defining measurable targets for efficient assessment. Whether an e-Government project has received effective assessment can determine its success or failure.

The United Nations Global e-Government survey states that e-Government measurements should track national progress, identify disparities in access to ICT, move toward an inclusive information society, and support international comparisons [62]. The U.N. global survey also examines governments' willingness to use e-Government to improve services to citizens. The survey contributed to the development efforts of the member states by focusing on whether e-Government impacts the socioeconomic uplift of the people. The survey provides a benchmark of a country's state of e-readiness (a country's preparedness to integrate technology into society). The objectives of the survey are to provide an appraisal of the use of e-Government to deliver social services and to provide a comparative assessment of the willingness and ability of governments to involve citizens in eParticipation.

The U.N. Global e-Government Survey presents a ranking of the countries of the world according to two indicators: (a) the state of eReadiness and (b) the extent of eParticipation worldwide. The 2003 survey shows that governments have made rapid progress worldwide in embracing ICT technologies for e-Government in the past years. In 2001, approximately 75% of U.N. member states use Internet in some capacity. By 2003, 91% of U.N. member states have a government Web site.

The U.N. survey also suggests that the evaluation of e-Government performance should be expanded from ex-ante to ex-post measurements. Additional suggestions from the survey are to differentiate between developing and developed countries, to identify different methodologies, and to develop criteria to make more equitable comparisons across countries. Clear guidelines enable countries to implement their e-Government projects more effectively.

Accenture introduces a concept of overall maturity of e-Government in evaluating the level of development of e-Government, and put forward an e-Government maturity model (eGMM) [22] which has four-level categorization. The categories consider the internal involvement of interested parties in the success of the project. The holistic four-level categorization for a country's e-Government maturity views the growth and development of e-Government as more than the mere presence of a Web. The four categories of the Accenture model are:

- Innovative Leaders—provide innovative Web-based solutions for citizens and businesses, like those of Canada, Singapore, and USA;
- Visionary Followers—strive to improve sophistication and administrative simplicity, like those of Norway, Australia, and Finland;
- Steady Achievers—steady improvements with less ambitious projects, like those of New Zealand, Hong Kong, and France;
- Platform Builders—new e-Government initiatives, like those of Japan, Brazil, and Malaysia.

The eGMM of Accenture presented above represents growth and development of e-Government as largely a linear process. According to this model, they contain three phases: information presence—the government has an available Web site; interaction—two-way interaction between government and stakeholders; and political participation—egovernance: voting and activism. It provides guidance on how to gain control of processes for developing and maintaining e-Government services, as well as how to evolve toward a culture of excellence in providing and managing e-Government. And its four stages are comprehensive and applicable to local, state and national-level projects.

A majority of the studies mentioned above are from the national perspective. To date, few theories or models has paid special attention to the local level governments. A relatively famous one that does consider the local level is the Municipal e-Government Assessment Project (MeGAP). It began as an effort to provide guidance to cities and communities as planners thought strategically about e-Government implementation [27]. These efforts, undertaken by Charles Kaylor at the University of Michigan and later at the Public Sphere Information Group (PSI Group), sought to identify the leading edge of municipal e-Government implementations by assessing the functions and services that municipalities were providing in a web-enabled form. By design, the assessment looks at the manner in which a function or service is provided on the web but does not evaluate the generic quality of the web site (e.g. navigability, quality, style) or extent of use by end users. Besides, MeGAP is lack of a firm theoretical foundation. Despite of this, it makes important contributes for the development of e-Government performance evaluation from local perspective. Flak et al. [12] applied it in the research of local e-Government in Norway. Their study did not offer tools to measure performance of public sector's services, and they used qualitative methods to complement the shortage of MeGAP.

There exist several initiatives for measuring e-Government. Most of existing research on local e-Governments, as well as that on national ones, is technology-oriented, however. IBM Center for The Business of Government provides a report on measuring the performance of e-Government [55], in which Stowers reported that among existing e-Government performance measures, customer satisfaction is the least used metric. There are two types of evaluation system: the technology-oriented assessment and the service-oriented assessment. The latter is the research direction of the future development of e-Government performance evaluation. The transformation from technology-oriented to service-oriented is needed.

4 Evaluating indicators and data

4.1 Evaluating indicators

The development of e-Government is an evolutionary process. An e-Government project can grow over time to include a variety of features, functions, and services. To achieve a comprehensive view of the evolutionary process, an understanding of constituent elements and overall objectives is necessary.

From the experience of United States and Canada which have higher level of e-Government and earlier assessment of development of e-Government, it can be seen that the future direction of e-Government evaluation will develop towards simplifying indicators and stressing the assessment of outcome as a whole. But the practical application of outcome should be measured from a broader perspective. For instance, in the construction of government web site, the number of online services does not ensure that citizens will be able to successfully access these services, and the availability of complex online services does not ensure that citizens are willing to use them. Online service delivery is not the full e-Government construction, it is just a kind of channel that government provides e-service. Furthermore, the provision of online service is just a transition process. The aim of government is not just proving online service, but is enhancing the service quality and bringing genuine benefit to citizens ultimately.

The report from IBM Center for the Business of Government points out that the evaluation of e-Government should be divided into three parallel parts, namely, input, output, and outcome. This is now generally recognized to be an academic classification [57]. Input measures cover the resources put into e-Government efforts; output part measures are those immediate actions resulting from e-Government efforts; outcome includes intermediate outcomes that are expected to lead a desired end, but which are not ends in and of themselves and the end, or ultimate outcomes that are the consequences of the program or those "end results that are sought". Our study assesses the status of local e-Government in China on the basis of this classification. It looks at the input, output and outcome of e-Government projects, with special emphasis attached to the practical application of outcome and the customer satisfaction. After comprehensive and careful investigation and discussion, we chose 15 evaluating indicators from input, output and outcome dimensions and set up an evaluating indicators system. The specific indicators are followed:

X1: Construction Invested Funds;
X2: Operation and Maintenance Invested Funds;
X3: The Number of Computer per official in the government;
X4: The Total Invested Funds Both of Internal and External Networks;
X5: The Utilization Ratio of Networks;
X6: The Number of Major e-Government Projects;
X7: The Number of Major e-Government Projects which have stable funds in operation and maintenance;

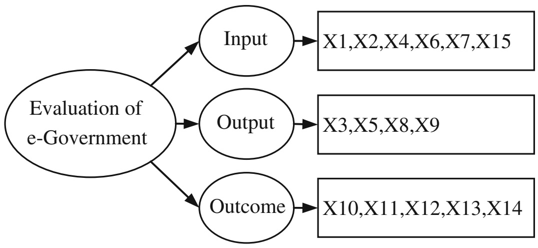

Fig. 3 The proposed evaluation model

X8: The number of administrative licensing items;
X9: The number of administrative licensing items which could be transacted via Internet;
X10: The Extent of Information Publicity;
X11: The Extent of Information Resources Sharing;
X12: The status of Customer Satisfaction;
X13: The formulation of Informationized system;
X14: The status of Information Security;
X15: The number of experimental e-Government projects.

All of these evaluating indicators are representative, and taken together they can assess the development of e-Government adequately. The proposed evaluation model is illustrated in Fig. 3.

4.2 Data source and data collection

Based on the evaluating indicators we put forward in the previous section, we commissioned China National Institute of Standardization (CNIS) to do a survey to obtain the development of local e-Government of the main coastal cities in east of China and several other major cities in the inland of China. All of these cities have high Internet penetration and mature ICT use. Some of the questions in the survey are directed at measuring use of government online services, degree of satisfaction, transparency of government affairs, extent of information sharing and so on which are designed from the service-oriented perspective.

Finally, we obtained a data set about the development status of 18 cities' e-Government development. This data set includes all of the evaluating indicators we needed. In the survey, Construction Invested Funds, Operation and Maintenance Invested Funds, The Total Invested Funds Both of Internal and External Networks are measured by ten thousand yuan; indicator of The Extent of Information Publicity is measured by the proportion of public information, it presents the transparency of government affairs. The Extent of Information Resources Sharing means the proportion of sharable information in all of the information provided by government. Customer satisfaction is an important evaluating indicator in assessment of e-Government, in the survey, this indicator was measured by whether or not an operation in the operation system of government was carried on a investigation in degree of satisfaction. In this survey, informationized system consists of four subsystems, which are information acquisition, updating and maintenance system, government information sharing system, government information publishing system and the directory of public government information. The formulation of Informationized system was measured by the number of the four subsystems that a local government had formulated. With regard to the survey of the information security, it had four questions: whether the government had carried out the risk assessment of information security; whether the government had formulated emergency plan of information security; whether the government organized emergency drill of information security and whether or not carried out the disaster back-up for the important information systems. Analogous to the indicator of the formulation of informationized system, the status of Information Security is measured by the number of the four works a local government had carried out. The last indicator is the number of experimental e-Government projects which is based on the growth of local e-Government. If a local government possesses a higher level of eGovenment, it will undertake more e-Government projects, which will improve service quality and bring genuine benefit to citizens and businesses they served.

5 Research methodology and data analyses

5.1 PCA and K-means clustering

The data we got were quantifiable with high dimension and each indicator may have high dependence. Data analysis methods are essential for analyzing this ever-growing massive quantity of high dimensional data. On one hand, high dimensional data are often transformed into lower dimensional data via the Principal component analysis (PCA) [26] where coherent patterns can be detected more clearly. PCA is among the oldest and best known techniques of multivariate analysis. It was first introduced by Pearson [44], and developed independently by Hotelling [19]. Like many multivariate methods, it was not widely used until the advent of electronic computers, but it is now well entrenched in virtually every statistical computer package.

The central idea of PCA is to reduce the dimensionality of a data set in which there are a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This reduction is achieved by transforming to a new set of variables, the principal components, which are uncorrelated, and which are ordered so that the first few retain most of the variation present in all of the original variables. Such unsupervised dimension reduction is used in a very wide range of areas such as meteorology, image processing, genomic analysis, and information retrieval.

On the other hand, cluster analysis attempts to pass through data quickly to gain first order knowledge by partitioning data points into disjoint groups such that data points belonging to the same cluster are similar while data points belonging to different clusters are dissimilar. One of the most popular and efficient clustering methods is the K-means method [17, 38] which uses prototypes or centroids to represent clusters by optimizing the squared error function.

A detailed analysis shows that there is a close relationship between K-means clustering and PCA which is extensively utilized in unsupervised dimension reduction. It is a common practice to first use PCA to reduce high dimensional data to a lower dimensional subspace and then apply K-means in the subspace [67]. In other cases, data are first embedded in a low-dimensional space and K-means is subsequently applied [41]. In this paper, we applied these two widely used methods to assess the development of local e-Government in China. In our study, PCA dimension reduction automatically performs data clustering according to the K-means objective function. The process and the results of analysis, which is obtained by using SPSS 16.0, are presented in the next section.

5.2 Data analysis and results

In this study, we used SPSS 16.0 to conduct PCA and K-means clustering. First, we presented the process and results of PCA analyzing. As we mentioned previously, the indicators in the data set we got with the help of CNIS had different units of measurement, so it appears that we need to standardize the variables in the first place. But PCA, like factor analysis, can be directly preformed on raw data, or on a correlation or a covariance matrix. If raw data are used, the procedure will create the original correlation matrix or covariance matrix, as specified by the user. As the variables in this study had different units of measurement, we specified the correlation matrix. Because if the correlation matrix is used, the variables are standardized and the total variance will equal the number of variables used in the analysis (because each standardized variable has a variance equal to 1). The correlation matrix conducted by SPSS 16.0 is listed below (see Table 1).

From the correlation matrix we can see that all the correlations are high, as the two variables seem to be measuring the same thing, so we could use PCA to reduce its high dimension. Otherwise, we need to do correlation test, as it is meaningful to conduct PCA only when the correlation test is eligible. Correlation test includes KMO and Bartlett's test. The results of the test see Table 2.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy—this measure varies between 0 and 1, with values closer to 1 being better and a value of 0.5 being a suggested minimum.

Table 2 KMO and Bartlett's test

Correlation test	Value
Kaiser–Meyer–Olkin measure of sampling adequacy	.588
Bartlett's test of sphericity	
Approx. chi-square	207.221
df	105.000
Sig.	.000

Table 1 The correlation matrix of indicators

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	1.000	.965	.267	.893	−.312	.401	.440	.695	.743	−.126	−.426	−.068	.166	.381	.680
X2	.965	1.000	.101	.933	−.224	.280	.328	.628	.672	−.104	−.481	−.046	.198	.314	.586
X3	.267	.101	1.000	.169	−.309	.217	.194	.445	.234	.032	.232	−.132	−.089	.413	.332
X4	.893	.933	.169	1.000	−.141	.224	.264	.575	.600	−.088	−.370	.125	.166	.302	.475
X5	−.312	−.224	−.309	−.141	1.000	.046	.056	−.405	−.330	.067	.068	.294	.296	−.175	−.314
X6	.401	.280	.217	.224	.046	1.000	.988	.069	.231	.016	−.030	−.235	.057	.327	.589
X7	.440	.328	.194	.264	.056	.988	1.000	.056	.204	.009	−.046	−.222	.052	.290	.597
X8	.695	.628	.445	.575	−.405	.069	.056	1.000	.792	.046	−.169	−.082	.192	.392	.461
X9	.743	.672	.234	.600	−.330	.231	.204	.792	1.000	−.080	−.335	−.136	.325	.411	.647
X10	−.126	−.104	.032	−.088	.067	.016	.009	.046	−.080	1.000	.347	−.156	−.529	.255	.086
X11	−.426	−.481	.232	−.370	.068	−.030	−.046	−.169	−.335	.347	1.000	−.087	−.154	.133	−.227
X12	−.068	−.046	−.132	.125	.294	−.235	−.222	−.082	−.136	−.156	−.087	1.000	.010	−.316	−.496
X13	.166	.198	−.089	.166	.296	.057	.052	.192	.325	−.529	−.154	.010	1.000	−.051	.062
X14	.381	.314	.413	.302	−.175	.327	.290	.392	.411	.255	.133	−.316	−.051	1.000	.373
X15	.680	.586	.332	.475	−.314	.589	.597	.461	.647	.086	−.227	−.496	.062	.373	1.000

This value in our study is 0.588 which is greater than the suggested minimum.

Bartlett's Test of Sphericity—this measure tests the null hypothesis that the correlation matrix is an identity matrix. If the Sig. is lower than 0.01, then we can reject this null hypothesis, which means the correlation matrix is not an identity matrix. This value in our study is eligible.

Given the above results of the two tests, it is valid to proceed with a principal component analysis.

The Communalities and Total Variance Explained are shown in Tables 3 and 4.

Table 3 Communalities

Indicators	Initial	Extraction
X1	1.000	.960
X2	1.000	.931
X3	1.000	.626
X4	1.000	.882
X5	1.000	.760
X6	1.000	.932
X7	1.000	.943
X8	1.000	.837
X9	1.000	.778
X10	1.000	.747
X11	1.000	.734
X12	1.000	.717
X13	1.000	.855
X14	1.000	.602
X15	1.000	.830

Communalities are the proportion of each variable's variance that can be explained by the principal components. The column of Initial means that the initial value of the communality in a PCA is 1, while the values in the column of Extraction indicate the proportion of each variable's variance that can be explained by the principal components. Variables with high values are well represented in the common factor space, while variables with low values are not well represented. In our study, we didn't have any particularly low values. The extracted principal components are shown in Table 4.

There are as many components extracted during a PCA as there are variables that are put into it. In this study, we used 15 variables, so we have 15 components. Eigenvalues are the variances of the principal components. Because we conducted principal components analysis on the correlation matrix, the variables are standardized, which means that the each variable has a variance of 1, and the total variance is equal to the number of variables used in the analysis, i.e., 15. The column of first total contains eigenvalues, % of Variance contains the percent of variance accounted for by each principal component, and Cumulative % contains the cumulative percentage of variance accounted for by the current and all preceding principal components. The three columns of Extraction Sums of Squared Loading exactly reproduced the values given on the same row on the left side of the table. The number of rows reproduced on the right side of the table is determined by the number of principal components whose eignvalues are 1 or greater. We extracted 5 principal components whose eignvalues were 1 or greater, and the cumulative percentage of

Table 4 Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	5.550	36.998	36.998	5.550	36.998	36.998
2	2.367	15.779	52.777	2.367	15.779	52.777
3	1.866	12.437	65.214	1.866	12.437	65.214
4	1.218	8.123	73.337	1.218	8.123	73.337
5	1.133	7.553	80.890	1.133	7.553	80.890
6	.919	6.124	87.014			
7	.539	3.596	90.611			
8	.479	3.193	93.804			
9	.430	2.867	96.671			
10	.222	1.483	98.154			
11	.140	.931	99.085			
12	.078	.522	99.607			
13	.049	.330	99.937			
14	.006	.039	99.976			
15	.004	.024	100.000			

Table 5 Component matrix (5 components extracted)

	Components				
	1	2	3	4	5
X1	.949	−.187	−.004	.158	−.010
X2	.879	−.309	.000	.245	−.044
X3	.383	.405	−.320	−.272	.373
X4	.802	−.329	−.033	.332	.134
X5	−.359	−.140	.575	.233	.476
X6	.520	.476	.659	.029	.014
X7	.530	.446	.677	.071	−.007
X8	.748	−.120	−.454	−.101	.216
X9	.828	−.177	−.184	−.153	.062
X10	−.067	.576	−.291	.567	.066
X11	−.363	.579	−.169	−.114	.475
X12	−.241	−.529	.029	.436	.434
X13	.199	−.482	.366	−.568	.356
X14	.519	.452	−.189	−.008	.305
X15	.811	.300	.126	−.093	−.241

variance was 80.89%, which means that the 5 principal components could explain 80.89% of all of the variance.

The correlations between the principal component and original variables are shown in Table 5.

This type of matrix is known as a matrix of factor or component loadings which are the correlations between the original variable and principal component. But the coefficients in this matrix are not the coefficient vector of principal component. The correlations divided by the corresponding square root of eigenvalue are the coefficients of principal component (see Table 6).

From Table 6 (italicized values), we could see that F1 can explain X1, X2, X4, X8, X9 and X15 well, and these indicators are evaluated from the entities of e-Government, such as input of manpower, material and financial resources. We classify these indicators into the dimension of project construction. F2 could be identified to X14, because F2 alone could explain X14 well. The indicator of X14 is the status of Information Security which means the evaluation of the information security management. So we define F2 as the dimension of information security management. X6 and X7 could be better explained by F3. They describe the major e-Government projects with stable funds in operation and maintenance. Both of them describe the special construction of e-Government, so we name F3 the dimension of special construction of e-Government. F4 only explains X10, i.e. the extent of information publicity, which presents the transparency of government affairs, so F4 is evaluated from the dimension of transparency of government affairs.

The last principal component F5 which can explain X3, X5, X11, X12, X13 is summarized from the dimension of informationized ability. Informationized ability includes the ability of personnel informationized, the utilization of network, the extent of information resources sharing, customer satisfaction and the formulation of informationized system. So we updated the proposed model we put forward in the 4.1 section, and the more accurate evaluation model is illustrated in the Fig. 4.

As mentioned above, in our study PCA is first used to reduce high dimensional data to a lower dimensional subspace and K-means is then applied in the subspace. In the process of PCA, we saved the component scores to the data set for use in the K-means clustering. There are 5 principal components, so 5 columns of component score were created in the data set accordingly. They are lower dimensional subspace of PCA. K-means clustering is conducted

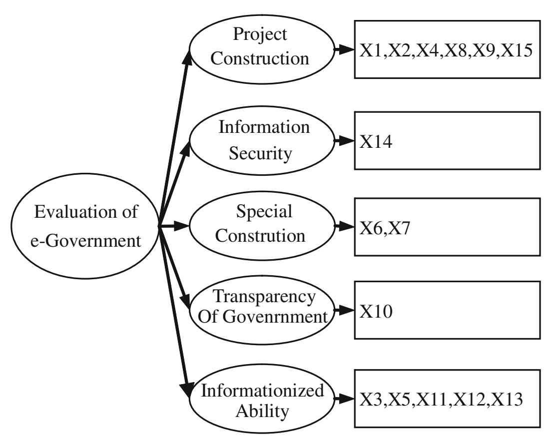

Fig. 4 The updated evaluation model

Table 6 The coefficients of principal component

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
F1	*0.40*	*0.37*	0.16	*0.34*	−0.15	0.22	0.22	*0.32*	*0.35*	−0.03	−0.15	−0.10	0.08	0.22	*0.34*
F2	−0.12	−0.20	0.26	−0.21	−0.09	0.31	0.29	−0.08	−0.12	0.37	0.38	−0.34	−0.31	*0.29*	0.19
F3	0.00	0.00	−0.23	−0.02	0.42	*0.48*	*0.49*	−0.33	−0.13	−0.21	−0.12	0.02	0.27	−0.14	0.09
F4	0.14	0.22	−0.25	0.30	0.21	0.03	0.06	−0.09	−0.14	*0.52*	−0.10	0.40	−0.52	−0.01	−0.08
F5	−0.01	−0.04	*0.35*	0.13	*0.45*	0.01	−0.01	0.20	0.06	0.06	*0.45*	*0.41*	*0.34*	0.28	−0.23

Table 7 Number of cases in each cluster

Clusters	Number	Cases
Innovative leaders	2	Beijing, Shanghai
Visionary followers	10	Shenzhen, Tianjin, Guangzhou, Dalian, Hangzhou, Ningbo, Xiamen, Jinan, Wuhan, Changchun
Steady achievers	4	Qingdao, Chengdu, Shenyang, Xi'an
Platform builders	2	Nanjing, Chongqing

on these scores. As introduced above, the e-Government maturity model of Accenture has four-level categorization: innovative leaders, visionary followers, steady achievers and platform builders. We used this eGMM to assess the local e-Government stages of growth of 18 cities in China, so we chose four clusters to conduct K-means clustering.

The final results implemented by K-means clustering are summarized in Table 7.

6 Discussion

This study presents, validates and updates an evaluation model of local e-Government system in China based on Principal Component Analysis (PCA). It captures the multidimensional and interdependent nature of e-Government system, and evaluates the local e-Government stages of growth of 18 cities in China via K-means clustering.

As previously introduced, according to socio-technical model (STM), humans and technology should be in supporting rather than antagonistic roles, and social context is so important that we should avoid the separation of social behaviors from technologies [28]. Additionally, the Stakeholder Theory envisions that e-Government projects involve a wide range of services, products, people and procedures. When conducting research of e-Government we should take into account the perspective of not only governments but also that of other key stakeholders such as citizens and businesses whom the government served. On the basis of these two theoretical foundations, we proposed our model, which can be described from three aspects: input, output and outcome. The evaluating indicators we chose especially emphasize the practical application of outcome and the customer satisfaction.

We conducted PCA on the data set and got five principal components which could explain more than 80% variance of all indicators, and those five principal components were defined into 5 dimensions. We then updated the initial proposed model, and got a more accurate evaluation model with 5 dimensions which captures the multidimensional and interdependent nature of e-Government. These 5 dimensions from which the updated model evaluates the development of local e-Government in China are project construction, which assesses the entities of e-Government, such as input of manpower, material, and financial resources; information security management, which evaluates e-Government in terms of the status of information security; special construction, which means the status of major e-Government projects a city has and of these with stable funds in operation and maintenance; transparency of government affairs, which means the extent of information publicity; and finally informationized ability, which includes the ability of personnel informationized, the utilization of network, the extent of information resources sharing, customer satisfaction and the formulation of informationized system. The updated evaluation model better assessed the development of local e-Government of 18 cities in China. In order to validate the success of the updated model, we conducted K-means clustering on the component scores which created from PCA, and got the results which could validate the accuracy and usefulness of the updated model and the evaluating indicators.

In accordance with the four level of Accenture's e-Government maturity model (eGMM), there are four clusters in the end of the K-means clustering. The results of K-means clustering indicate that Beijing and Shanghai are in the first level of Accenture's e-Government maturity model (eGMM). They are innovative leaders in the local governments of China, and provide innovative Web-based solutions as well as an array of basic online services for citizens and businesses to satisfy their demand. This is not surprising considering that Beijing is the capital of China and a center of politics, culture and international exchange and Shanghai is an international metropolis, an important economic and trading center all over the world. 10 of 18 cities, we investigated, such as Shenzhen, Tianjin, and Guangzhou, are at the second level, i.e. visionary followers. Most of them are the coastal cities in east of China with relatively rapid economic development. Qingdao, Chengdu, Shenyang, Xi'an are in the steady achievers level, which have steady improvements with less ambitious projects. All these cities except Qingdao are in the inland of China. Shenyang is in the northeast of China which is the old industrial base, but the development of northeast of China is laggard compared to the eastern coastal cities of China. Although Qingdao is a very famous seaside tourist city in China east, it is not the capital city of a province. This perhaps explains why its economy is developed rapidly but the development of e-Government is not as rapidly. Finally, Nanjing and Chongqing are in the final level of the eGMM, i.e. platform builders. They are new e-Government initiatives, which accord with the development of economy. The results of K-means clustering are identical to the comprehensive development of every aspect of these 18 cities of China, which, in turn, confirms the validity and rationality of the evaluation model and the evaluating indicators we chose.

The ultimate objectives of the study are to propose and test the integrated model to enhance and improve both the understanding and knowledge of e-Government evaluation in practice and then to explore the phenomenon of local e-Government in China. At the same time, lessons learnt from the empirical work have been elicited to help inform practice. These lessons have been developed by the authors in order to help improve e-Government evaluation practice. First of all, the evaluation should focus on to the social environment and stakeholders who have close interest in the government, so the indicators of public service are becoming more and more important to the evaluation of e-Government. Secondly, national and local e-Government projects have different goals, objects and constraints [53], so it is necessary to differentiate between them, before the evaluation of e-Government becomes more meaningful and effectively improve the understanding of e-Government.

7 Conclusions

Over the last few years, more and more attention from all over the world has been paid to the area of e-Government. However, previous researches mainly focus on the development and evaluation of a Web site that interfaces between a government and its citizens, and these are called technology-led researches. IBM reported that customer satisfaction is the least used metric among existing e-Government performance measures and the research direction of the future development of e-Government evaluation should be transformed from technology-oriented to service-oriented. Furthermore, majority of the investigates in those previous researches are designed from the national perspective, while significantly less has been available with reference to the local governments, which does, in fact, have the most direct contact the greatest impacts on their citizens. So the future research should center on local e-Government.

In accordance with the research direction, this study assesses e-Government projects at the local level from the service-oriented perspective which assesses the status of local e-Government of the main coastal cities in east of China and several major cities in the inland of China, all of them with high Internet penetration and mature ICT use. We chose 15 evaluating indicators to propose the initial evaluation model, and we used principal component analysis and K-means clustering to do the empirical study, finally got the updated model with five more accurate dimensions and 4 clusters based on the eGMM of Accenture, each cluster accords with the level of eGMM of Accenture, and different cities belong to different cluster which means that they are in different stages of e-Government growth. The results of this study are identical to the comprehensive development of every aspect of these 18 cities of China, so we consider the updated model and those evaluating indicators are valid and reasonable.

Even though the rigorous procedure allowed us to develop and validate an evaluation model of e-Government, this empirical study has several limitations which could be addressed in future researches. First, although the indicators this study chose are representative and could roundly assess the development of e-Government, different e-Government projects have different contents, evaluating indicators might be different according to the different projects. But the dimensions of the updated model are effective and successful. More testes need to be taken to validate their implications to the evaluation of e-Government. In addition, the sample size used is another limitation of this study. The data set includes 18 cities which have high internet penetration and mature ICT use and most of them locate in eastern coastal of China, while the other cities located in west of China are not investigated, which, results in that the study didn't cover all the cities in China. Additional research efforts are needed to evaluate the validity of the investigated model, further extend the evaluating indicators and add the sample size.

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