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RESEARCH ARTICLE

Identifying critical challenges in the adoption of cloud-based services

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Summary

Cloud computing provides a way to integrate and share information on a real-time basis across an organization. The current organizations are adopting the cloud services to gain competitive advantage in real-time data sharing. To meet the current demand in semiconductor industries, they must develop better techniques to produce electronic products at low cost and in a large scale. Adoption of cloud-based services may resolve the fastest growing demand of technical advancement of semiconductor industries. The research presented in this paper is based on an analysis of the data obtained from the semiconductor sector. This study identifies the critical challenges associated with the cloud service adoption in semiconductor industries. Twelve critical challenges have been identified that need to be overcome for adopting the cloud services for any semiconductor industry. These are network/Internet availability, data security, integration of various services, monitoring of data and services, maintenance of computing performance, liability, power outage, service interruption, organizational change, business complexity, legal issues, and lack of awareness.

KEYWORDS

challenges, cloud computing, hypothesis testing, semiconductor industries, t-test

1 | INTRODUCTION

Adoption of cloud services has been a steady boost in current business world. Many organizations have already made an attempt to adopt this technology to integrate their business. Several organizations have already identified some particular methodologies for applying cloud services in their existing business process. Mehrsai et al (2013) suggested that there should exist an effective collaboration between the cloud service provider and the organization to have a better result.

Technological advancement has increased the demand of integrated circuits (ICs) design and manufacturing by 8% to 10% per year.[1] The competitive market has forced the industries to design and manufacture more cost effective products. For reducing the product cost, an organization needs to adopt advanced technology to produce its products at a larger scale. Since further advancement of semiconductor technology is continuously taking place worldwide, the semiconductor industry is playing a key role in development of countries such as Japan, Germany, France, U.K, and United States. In the United States, the semiconductor sector has grown around 9% each year since 1987 compared to less than 4% in other sectors.[2] The base of the semiconductor technological progress is described by Moore law and followed by the International Technology Roadmap for Semiconductors. According to Moore law, there is a noticeable trend in the semiconductor industry, the number of transistors that can place on an IC is increasing exponentially and doubling approximately every 2 years.[3] The semiconductor industries are taking a lead among all industries in the world for more than a few decades. The development of microchip products is pretty complicated because of the complexity of circuits and material properties as well as process complexity.[4] The semiconductor industry is one of the fastest growing sectors of the global economy and bears the promise to be the key industry in the future, although such an industry is considered as one of the most complex industries in world. It is so not only because of much complexities in the processing steps involved in device manufacturing but also because of volatility and unpredictability of demands. As described by the International Technology Roadmap for Semiconductors, staying on the productivity curve has become more difficult for long time as technological and business challenges are growing rapidly. The acceleration of complexity increases continuously because of rising cost of technological development as well as unpredictable variable demands and continuously shrinking device dimensions. In semiconductor industry, time to market plays a very important role in being successful in the business.[5] The semiconductor industry today has become one of the largest and most complex industries in the world. One of the biggest challenges associated with the semiconductors is that they are always moving toward smaller dimensions. The combination of device complexity, market forces, and industrial policies is creating powerful motive to shift new chip production with new features. Production of chips with new features in limited time and reduction in cost is always a challenge for researchers as well as for companies.[6] The past decade has witnessed a tremendous growth in semiconductor industries, which has enabled them to offer new products in market with moderate cost and in limited time. Over the last few decades, there have been many significant changes, including miniaturization of device dimensions and rising cost of research and development. On other hand, fabless design companies and foundries have been able to meet the demand with silicon process technology having lower cost and high performance device. Fabless design refers to the design of hardware devices and semiconductor chips. The low cost and high performance attributes have worked out very well in semiconductor industries to face growing demands with better performance. Development of fast prototype model along with appropriate modification of design is essential requirements of a modern semiconductor industry. To achieve these goals, most of world's largest semiconductor industries, such as Intel, Cadence, and TSMC[7] started implementing the cloud services in their industries. Cloud service is quite easy to develop and does not require extensive information technology (IT) infrastructure in terms of hardware and software. Cloud-based services in semiconductor organizations require Internet, and so it is quite easy to implement these services for an organization. The main objective of adopting of cloud technology in semiconductor organizations is to reduce the design complexities of ICs along with resource utilization for maximizing efficiency and reduction of cost. It may be mentioned here that “efficiency” is judged not only by reduction in cost, but it also checked whether the existing customers are happy and at the same time the revenue is satisfactory.

However, adoption of any new technology services is always accompanied by some challenges. Adoption of cloud-based services in semiconductor industries is no exception. This paper aims at identifying the critical challenges for the adoption of cloud services in semiconductor industries.

2 | BACKGROUND AND MOTIVATION

Supply chain management (SCM) has enhanced the success in adopting the successful IT and information system (IS) in various business practices today. The integration of IT and IS with cloud computing has improved the organizational performance drastically. Cloud-based services could shift the traditional plan-driven projects to a new technology-driven management. Different authors, including Gens,[8] Leukel, et al,[9] Pearson and Benameur,[10] Chien,[11] Morgan and Conboy,[12] Hsu and Yang,[4] Huang et al,[13] and Misra et al[14] made an attempt to give a comprehensive overview of cloud services and cloud computing and their implementation in business practices.

The concept of cloud has been introduced in the early 1990s. Kalakota and Whinston[15] made a brief discussion on the prospects of application of Web-based SCM and the usage of Internet and SCM. The authors also dwelt on the prospering opportunities in a greater detail. There are also several challenges in adopting the newly developed services. Rimal and Choi[16] has identified some of the challenges. However, they had also pointed out the opportunities with cloud services. Hong et al[17] gave a comprehensive overview for the IS integration with the current business process. In the same year, Aleem and Sprott[18] and Lenart[19] portrayed cloud computing as one of the most useful technologies for sharing and integrating information in any organization. Challenges for the adoption of different technologies have been discussed in various literature authored by Rimal et al,[16] Hsu et al,[4] Huang et al,[13] Zhang et al,[20] and Misra et al.[21]

With the development of ICs, small chip size increases the complexity of logic circuit. The bottleneck in IC design is its strong dependency on requirement of the state of art equipment, especially for small and medium-sized industries that do not have the ability to have strong servers or hardware acceleration simulation. Various tools are required in IC designs, and so cost associated with them is a big problem for medium and small-sized organizations. Apart from the cost factor for purchasing of purchased electronic design automation (EDA) tools, its inefficient utilization makes it becomes costlier in the case of medium- and small-sized companies. Some parts of equipment remain unused, which lead to waste of resources.[22] However, production in semiconductor manufacturing industries due to technological advancement in IC manufacturing continues to increase about 8% to10% per year to fulfil the demands.[1] For the cost to be reduced, big firms need to transfer the manufacturing technology from 1 country to another. Cloud technology helps to manage the various resources of a company by integrating the information of processes spread across the world (Wu, 2014). Adoption of cloud services and appropriate techniques enables companies to use maximum resources with minimum effort and also enhances computing performances such as simulation verification. This brings about reduction in the design complexity.[23] Using cloud-based services, the hardware and software resources can be shared to different individuals or organizations.

However, adoption of a new technology usually leads to several technical, organizational as well as social and economic challenges. Several researchers have pointed out that there are challenges that are faced by any industry when it wants to electronize its databases. Misra and Bisui [24] and Misra et al[25] have identified the critical challenges in the electronization of health care industries. Gupta et al[14] have identified the challenges that exist in the adoption of cloud-based enterprise resource planning (ERP) system. It may be maintained that cloud manufacturing and cloud EDA are relatively new areas of research. This communication includes exhaustive literature review on the related domains, such as studies conducted on adoption of cloud technologies in semiconductor industries. A systematic discussion on cloud EDA and cloud manufacturing benefits and challenges has been made here. It is worthwhile to point out here that not many academic papers are available in the adoption of cloud services in semiconductor industries. The present paper will find important application in adoption of cloud services in semiconductor industry and can be regarded as a significant step forward in further moderating different industries, more particularly the semiconductor industries.

3 | THEORETICAL BACKGROUND AND CHALLENGES

By performing an intensive literature survey, we have detected out various possible challenges that the semiconductor industries are likely to face while adopting cloud services for semiconductor industry while adopting cloud services. In this section, we have an attempt to enlist them. This list of challenges will be used as a preliminary framework during our research work. In semiconductor industries, the complexity arises from a number of sources: technical, economical, business, etc. In Table 1, a summary of variables used as challenge (ch) is mentioned along with the respective references.

The detailed descriptions of the variables used are given below.

Maintenance of performance guarantees: Cloud-based services in semiconductor industries have performance related in risks relation to bandwidth, speed, reliability, and outage of services. By cloud computing, we mean remote accessing of cloud services. The gap in communication time between the client and the Web server is one of the major problems for cloud services. For semiconductor industries also the computing performance can be an issue.[26] As mentioned earlier, semiconductor industries are the world's largest industries, and they contain huge data. The implementation of cloud services in semiconductor industries is challenging, because it involves transfer of data via Internet.[27] It is hard to offer performance guarantee when sets of servers in a cloud environment keep running for continuously changing populations of thousands or millions of jobs.[27,28] The more is the users connected to the same server, the more chances of poor performance.[29] If the cloud environment is not built on advanced technologies, it cannot be efficient. This is likely to become very serious for semiconductor industries.

Assertion: Maintenance of computing performance in cloud semiconductor is a critical challenge.

Data security: Cloud computing in semiconductor industries is a planned approach to provide flexible computational and storage services to clients over Internet. The security of computer systems and the data stored in them can be compromised in several ways, and none can provide 100% security guarantees.[26] This is major hurdle towards its broad

TABLE 1 Definition of variables in literature and proposed in this study

Variable	Definition	Related literature
Maintenance of computing performance (Ch1)	The continuous maintenance of standard computing services by cloud service provider	26–29
Data security (Ch2)	Maintenance of the security concerns of the information stored in cloud server	26,27,30
Liability (Ch3)	Issues raised due to mismanagement of data and services	27
Legal issues (Ch4)	Different privacy laws and regulations of different countries	Hogan, 2011 Heiser, 2008
Lack of awareness (Ch5)	Project managers unawareness about the benefits and usage of cloud services	Wu, 2014[28]
Service interruption (Ch6)	Interruption of cloud services due to various reasons	26
Integration of various services (Ch7)	Integration of different sectors using cloud services for a large semiconductor industry	26
Monitoring of data and services (Ch8)	Monitoring of data and information in large cloud-based semiconductor organization	Foster, 2008
Network/Internet availability (Ch9)	Semiconductor manufacturing operation is a long time running process, weak and off-connection is harmful for business and process	22
Power outage (Ch10)	Uncertainty of power will disrupt the services and hamper the semiconductor industry in its workflow	31
Organizational change (Ch11)	Difficulty in adopting new technologies and changes in the work culture	7
Business complexity (Ch12)	Expansion of business among large organizations or expanding to new geographies creates a management issues for cloud service providers to keep up to these expansions and have flexibility	7

Abbreviation: Ch, challenge.

acceptance in cloud semiconductors. In conventional semiconductor industries, sensitive and confidential data of each organization are kept under one's own control at its own physical location. Although in cloud-based semiconductor organizations data is stored in the server, the clients do not know the physical location of the servers. Data centers can be located in any country. Therefore, data security is one of the critical challenges for cloud semiconductor industries or organizations.[27,30]

Assertion: In cloud semiconductor industries, data security is one of the critical challenges.

Liability: Cloud services in semiconductor industry can generate liability issues when expanded to multiple departments in large organizations or expanding to new geographies or new business area. When a semiconductor service provider puts their IP on servers outside of their control, liability issues open up. The valuable data of clients is stored offsite on cloud, collected with other customer. Thus, liability is another serious challenge in implementing of cloud services in semiconductor sectors for service providers.[27]

Assertion: Implementation of cloud services in semiconductor industries creates a liability issue for service providers and users.

Legal issues: Various types of privacy laws and regulations exist in different countries at different levels (ie local and national levels). This is a complex issue for cloud implementation. An organization has a responsibility to operate in agreement with these regulations.[17,32] Cloud semiconductor is fairly a new concept, and therefore, there is a need to have well-defined standards and procedures for every country. Rules and regulations can facilitate security and integrity of the corporate data and information security. Cloud service providers would like to store their database near optimal source of network connectivity and power resources. This may lead to jurisdiction problems for many users of those services, as there are national and international laws that define requirements for physical data and location that companies need.

Some examples of privacy laws and regulations are given below.

In the context of cloud services, there are distinct rules and regulations for every country. They need to be followed strictly to secure the privacy of the corporate data, when an industry goes for adoption of cloud services. Any organization is legally obliged to protect the privacy of the data for all their employees and customers. Use of some data for any purpose other than that for which they were collected is prohibited by law. For example, data collected on the health of the employees of a particular organization cannot be used for charging the smokers to raise the premium of health insurance (Technet Magazine, https://technet.microsoft.com/en-us/magazine/jj554305.aspx).

Also, some type of data cannot be shared with other parties. However, In today's modern world of cloud computing, it is extremely difficult to maintain the privacy of data, since adoption of cloud services necessarily involves a third party who takes care of the operations and management of the entire infrastructure. In this way, the cloud service provider has access to all the data.

When cloud services are adopted by multinational companies, they must be very particular to see that use of any data deployed to the cloud does not violate the laws and regulations, which are followed by all the employees, foreign counter parts, and all third parties. It is worthwhile to mention here that the laws regarding cloud computing/services of 1 country can be much different from the laws prevalent in some other country. The data privacy laws and cloud adoption regulations of different countries of the European Union, Australia, and some other countries are too complex. The Australian national privacy act (Http://www.privacy.gov.au/law) provides stringent regulation for different organizations giving guidelines regarding collection of data, their use, security, and disclosure of personal information. In Australia, different financial services organizations need to follow very strict regulations regarding cloud services.

Assertion: Legal issues may be a challenge in adopting cloud services in semiconductor industries.

Lack of awareness: The cloud semiconductor (ie eManufacturing and design) is comparatively a new technology, which is used by a number of customers. They share the same platform by using cloud services. This is a special application of cloud technology in semiconductor industry (Wu, 2014). Awareness is one of the success factors in adopting this new technology. But in an organization, it is quite likely that there is a lack of knowledge about cloud computing services as well as lack of experience in companies as to how to switch over to cloud services properly.[28] The project manager and the top management of the semiconductor industries may not have proper knowledge and experience of cloud adoption and usage of such transition.

Assertion: Lack of awareness is a challenge for adopting this new technology.

Service interruption: Cloud-based service allows users to use major computing services via the Internet. However, for doing this the availability of services, like, EDA tool might be a major issue. Service interruption may be temporary or permanent. Temporary interruption of services is unavoidable. It may happen any time and for any duration.[26] Especially in any cloud semiconductor industry, service interruption will be very harmful, particularly when some process is going on. Uninterruption in design and manufacturing process is very much desirable.

Assertion: Service interruption is one of the major challenges for cloud services in a semiconductor sector.

Integration of various services: Technically, integration of services (eg different EDA tools and services) is a very complex issue for cloud implementation in semiconductor industries. These industries prefer migration to cloud computing through a hybrid model. In such a case, they keep some elements under their direct control and outsource only the information that is less sensitive. However, in cloud services the semiconductor industries might have to integrate with more than 1 service provider. They need to share all their applications and data to get the best outcome. This may be leading challenges for the project managers to integrate with various service providers.[26]

Assertion: Integration of various services in cloud semiconductor is a challenge for large organization.

Monitoring of data and services: Cloud computing technology is mainly governed by the concept of virtualization. One challenge that virtualization brings to cloud technology is the potential difficulty in fine control over monitoring of resources (Foster, 2008). The management and monitoring in large cloud-based semiconductor organizations are very important for service providers. Poor monitoring and management may lead to information loss. This can lead to financial loss as well as losing business insight. This may be more critical for a large organization.

Assertion: Over all monitoring of data and services in cloud semiconductor industry is a critical challenge for service provides and consumers for very large organization.

Network / Internet connection: Cloud-based services need a continuous interconnection for all real-time transactions to take place. Internet is required to connect both the services and documents. Even one's document cannot be accessed in weak or off-state Internet. Good Internet connection helps to optimize the output and performance of cloud-based services in both semiconductor design and manufacturing. Internet dependency is sometimes intermittent and not conductive to or conducive to continuous operations in manufacturing and design. Since semiconductor manufacturing operation is a long time running process, weak and off connection is harmful for business and process.[22]

Assertion: Semiconductor manufacturing and design processes depend on network/Internet availability.

Power outage: Modern cloud service provider equips their power supply system with multisources to mitigate power cost, carbon emission, and power outage. Power outages are major causes of service downtimes for a cloud-based industry and may be a critical challenge. Both temporary and permanent outages have critical adverse reactions to the services that are provided by the cloud vendor. Permanent outage may occur because of the supplier's discontinuation of business. Temporary power outage appears to be inevitable.[31] The power outage reason may be technical (ie technical fault) or natural (eg storm). There is no specific time and duration of power outage. It may happen anytime for any duration. Therefore, this uncertainty of power supply may disrupt the services and hamper the semiconductor industry in its workflow. For cloud semiconductor, power interruption will be harmful for both cloud and semiconductor businesses.

Assertion: More power outage in cloud supply may harm the semiconductor industry in its workflow.

Organizational change: It is a process in which organization changes its structure, policies, and technologies. The success of cloud service implementation in semiconductor industry depends on positive desire of an organization to undergo change. It is very difficult for an employee to adopt new technologies, because it changes the work culture of an organization and may not compatible with it. Since cloud infrastructure is very complex, the said type of changes may bring in additional difficulties for cloud implementation. Complex infrastructure, network dependency, data security, and loss of confidentiality may also cause further difficulties in implementing cloud service.[33] Implementation of cloud service in semiconductor requires a huge investment in advance. This also may pose hindrance to implementation of cloud services in semiconductor sectors.

Assertion: Organizational changes may be a critical issue for a cloud service adoption for semiconductor industry.

Business complexity: Semiconductor industries work in a large setup. Sometimes industry is spread over several locations. Usage of cloud computing requires an integration of all the sectors so that they can work simultaneously. However, to integrate all the sectors and the huge amount of data, information, and design, the cloud services will have to have a complex architecture. The project manager of both the cloud and semiconductor industries needs to handle such a complex architecture. Currently, ERP is used for integrating various business functions of a manufacturer. Adoption of cloud-based services requires the integration of cloud with ERP system. This may lead to more complexities in the system. For a large semiconductor industry, it may pose challenge to use the services optimally. Expansion of business among large organizations or expanding to new geographies creates a management issues. It can be more difficult for cloud ERP to keep up to these expansions and have flexibility. The business complexity of a cloud semiconductor depends on the size of an organization.[7]

Assertion: Business complexity is a challenge for cloud service implementation in semiconductor sectors.

4 | QUESTIONNAIRE DESIGN

On the basis of the literature survey, we have identified 12 variables that may have significant impact on the adoption of cloud services in semiconductor industries. In the next phase, we have made a survey questionnaire (given in the Appendix) to collect the viewpoints of both the cloud service providers and semiconductor industries. Our survey form consists of mostly closed-ended questions. However, we had asked an open-ended question asking the respondents about any additional comments on the survey design and challenges. We have received a few feedbacks. Our survey form consists of 12 questions regarding the challenge variables, where the respondents are required to mark their response in a 5 point Likert scale. Additionally, we also had some questions, which captured some background information of the survey respondents. In our next phase, we proceed with the data collection process.

4.1 | Data collection

It was a challenge to identify the sample population for our survey. The survey questionnaire was sent not only to cloud services providers and semiconductor industries but also to other industries and educational sectors. We had identified the respondents by checking their background and experience. Survey forms were sent only to those who have relevant knowledge on both cloud and semiconductor industries, or who are studying or pursuing researches in similar fields. We aimed at collecting around 200 responses. To achieve this target, we surveyed online using e-mail, linkdin, and other similar technologies, as well as offline, in which case where we met to the respondents personally with a printed survey form. A total of 1 000 questionnaires were distributed (by sending messages through e-mails, linkdin and facebook, and personal visit), out of which 188 duly filled responses were received. Our statistical analysis has been performed on these 188 responses. We have given brief backgrounds of our respondents in the next section. At the last section of our survey form, we also requested the respondents to mark the easiness of answering our survey. Most of them responded that they found no difficulty in responding to questions. Eight respondents marked our questionnaire as "very difficult," whereas 25 said that it is somewhat difficult. Eighty nine responded as "average," 53 marked "easy," and 13 marked "very easy."

4.2 | Demographic background of respondents

In our survey form, we asked the respondents to mark the type of organization they belong to. It was marked as "mandatory" answer. Therefore, we received 188 responses for this question. A pie chart (Figure 1) has been given to summarize the types of organizations. Similarly, we have given pie charts (Figures 2, 3) for presenting the size of the organizations, the respondent belongs to, and the number of years of experiences of the respondent in the related area.

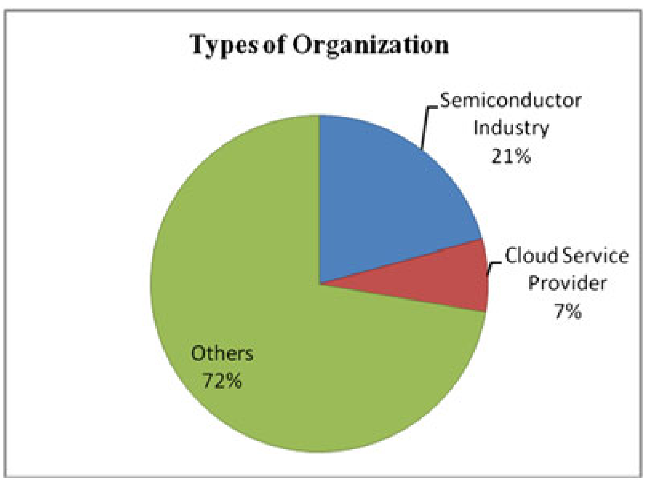

FIGURE 1 Types of organization

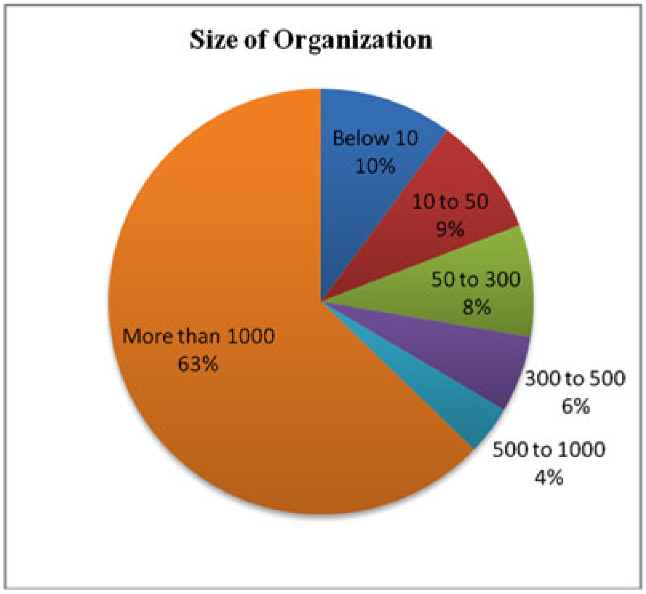

FIGURE 2 Size of organization

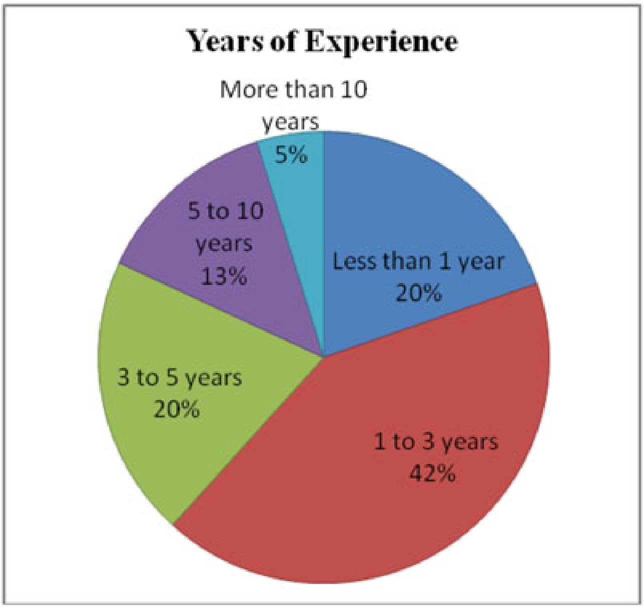

FIGURE 3 Years of experience

5 | ANALYSIS

Collected data have been analysed using the statistical software SPSS 16.0. A dataset has been prepared from the survey response sheet. The 5-point Likert scale responses have been replaced by numeric values. "Strongly Disagree" has been replaced by 1, "Disagree" has been replaced by 2, "Neutral" has been replaced by 3, "Agree" has been replaced by 4, and finally, "Strongly Agree" has been replaced by 5. A check for missing values has been done manually. We found no missing values in our dataset. In the next phase, the reliability of our dataset has been assessed. To check the reliability, we have performed Cronbach alpha test.[34] A Cronbach alpha value greater than or equal to .7 indicates the internal

TABLE 2 Reliability statistics

No of items (N)	Cronbach alpha
12	.792

consistency of the dataset.[35] For the present analysis, Cronbach alpha value for the dataset used was found to be .792 (Table 2). This implies that dataset is reliable and can be used for further study.

We have performed 1 sample t-test to identify the significance of the challenges. The statistical formula for 1 sample t-test is, $t = \left(\frac{\overline{X}-\Delta}{\frac{S}{\sqrt{n}}}\right)$, where $\overline{X}$ denotes the sample mean and $\boldsymbol{\Delta}$ is the test value (3 in our case), with the t-test is to be conducted. S represents standard deviation, while n is size of the sample. For the present study, n = 188 and Δ = 3. The t-test has been conducted with these values.

TABLE 3 One-sample statistics

	N	Mean	Std. deviation	Std. error mean
Ch1: maintenance of computing performance	188	3.79	.882	.064
Ch2: data security	188	4.09	.985	.072
Ch3: liability	188	3.73	.817	.060
Ch4: legal issues	188	3.38	.822	.060
Ch5: lack of awareness	188	3.26	.960	.070
Ch6: service interruption	188	3.64	.905	.066
Ch7: integration of various services	188	3.86	.802	.059
Ch8: monitoring of data and services	188	3.80	.871	.063
Ch9: network/Internet availability	188	4.10	.940	.069
Ch10: power outage	188	3.72	.931	.068
Ch11: organizational change	188	3.54	.849	.062
Ch12: business complexity	188	3.45	.879	.064

Abbreviation: Ch, challenge.

The results of 1 sample t-test have been represented in Tables 3 and 4.

Table 3 gives the mean value of each variable. The standard deviation and standard error mean has also been shown in this table.

Table 4 provides the final results of 1 sample t-test where the values have been computed by considering the test value to be the lower and upper limits of 95% confidence interval (CI) for all the 12 challenges have also been presented in Table 4. The computed t-value for 95 % CI and 187 degrees of freedom (df) is 1.96 approximately. One may observe that variables (challenges) with t-value greater than 1.96 are significant in this study. In our study, we may observe that all the 12 challenges variables have t-value greater than 1.96 and significance level less than 0.05. From these data, one arrives at the conclusion that all 12 challenges discussed in this paper are significant in the adoption of cloud services in semiconductor industries.

Moreover, the method of descriptive statistics (see in Table 5) has been used to gain a more detailed view of the challenges. We have also ranked the challenges (variables) using the mean value of the sample. The ranking has been presented in Table 6.

Finally, factor analysis has been done to cluster the variables. The feasibility of performing factor analysis was first checked by using Kaiser-Meyer-Olkin (KMO) and Bartlett Tests. Table 7 gives the KMO and Bartlett test of sphericity values. We may observe that in our study, KMO value is 0.780, which is greater than the cut off value 0.5. The Bartlett test of sphericity significance level is also less than the cut off significance 0.05. Thus, we can now proceed further for doing factor analysis.

The outcome of the factor analysis has been presented in Table 8 and Figure 4. From Table 8, we observe that only the first 4 components have accounted for eigenvalues greater than 1. This observation implies that a maximum of 4 factors

TABLE 4 One-sample test

	Test value =3					
					95% Confidence interval	
	t	df	Sig. (2-tailed)	Mean difference	Lower	Upper
Ch1: maintenance of computing performance	12.237	187	.000	.787	.66	.91
Ch2: data security	15.178	187	.000	1.090	.95	1.23
Ch3: liability	12.325	187	.000	.734	.62	.85
Ch4: legal issues	6.386	187	.000	.383	.26	.50
Ch5: lack of awareness	3.724	187	.000	.261	.12	.40
Ch6: service interruption	9.752	187	.000	.644	.51	.77
Ch7: integration of various services	14.724	187	.000	.862	.75	.98
Ch8: monitoring of data and services	12.650	187	.000	.803	.68	.93
Ch9: network/Internet availability	16.068	187	.000	1.101	.97	1.24
Ch10: power outage	10.576	187	.000	.718	.58	.85
Ch11: organizational change	8.766	187	.000	.543	.42	.66
Ch12: business complexity	7.051	187	.000	.452	.33	.58

Abbreviation: Ch, challenge; df, degrees of freedom.

TABLE 5 Descriptive statistics

	N	Minimum	Maximum	Mean	Std. deviation
Ch9: network/Internet availability	188	1	5	4.10	.940
Ch2: data security	188	1	5	4.09	.985
Ch7: integration of various services	188	1	5	3.86	.802
Ch8: monitoring of data and services	188	1	5	3.80	.871
Ch1: maintenance of computing performance	188	1	5	3.79	.882
Ch3: liability	188	1	5	3.73	.817
Ch10: power outage	188	1	5	3.72	.931
Ch6: service interruption	188	1	5	3.64	.905
Ch11: organizational change	188	1	5	3.54	.849
Ch12: business complexity	188	1	5	3.45	.879
Ch4: legal issues	188	1	5	3.38	.822
Ch5: lack of awareness	188	1	5	3.26	.960
Valid N (listwise)	188				

Abbreviation: Ch, challenge.

can be extracted from the data. Figure 4 portrays the scree plot of the data. This Figure confirms our former assertion that only 4 components have eigenvalues greater than 1. Therefore, scree plot has also confirmed about the extraction of 4 factors.

The extracted factors computed by us have been presented in Table 9. The results presented in the scree plot also tally with these of the principal component analysis. Variables with factor loadings greater than 0.5 have been considered in the computation of components. The factor loadings have been highlighted in Table 9.

From the principal component analysis, we could make an observation that 12 challenges (variables) have been clustered into 4 components. The first component consists of the variables data security, liability, service interruption, network/Internet availability, and power outage. While the second component consists of maintenance of computing performance, integration of various services, and monitoring of data and services, the third component contains organizational change and business complexity, and finally, the fourth component contains 2 variables representing legal issues and lack of awareness. Here, we make an important observation that the challenge variable liability has factor loading greater than 0.5 for both components 1 and 2. However, we have put this variable in component 1 as the factor loading is higher in component 1 than in component 2. A detailed analysis of each and every challenge variable has been done in section 6. We have also named the grouping of the variables, so that semiconductor industries could analyze them with ease.

TABLE 7 KMO and Bartlett test

Kaiser-Meyer-Olkin measure of sampling adequacy.		.780
Bartlett test of Sphericity	Approx. Chi-Square	551.703
	df	66
	Sig.	.000

Abbreviation: Ch, challenge; df, degrees of freedom.

6 | DISCUSSION

To facilitate our research findings in real life problems related to semiconductor industries, we presented in this section a detailed discussion. In the present study, a total of 12 variables have been identified as critical challenges that are likely to be faced while adopting cloud services in the semiconductor industries. The statistical analysis presented in section 5 clearly reveals that all 12 variables are statistically significant. All the identified challenges are critical, as they have direct or indirect effect in the success of the project. The discussion presented below is based upon intitution. It elucidates the possible reasons behind the criticality of all 12 variables.

1. Maintenance of computing performance**:** In a cloud semiconductor industry, the cloud service provider must have to maintain a minimum standard of the server performance to get the best out of it. However, in the present world, Internet connectivity is a serious issue. Therefore, there is no guarantee that the cloud service provider will be able to maintain the standard level all the time. In our study, the data have been collected mostly from India. There is no such cloud service provider who would be able to guarantee a service for high computing. Therefore, this variable is likely to turn out to be a significant challenge. However, this challenge may be a bit less critical for technically developed country. The respondents have ranked this challenge as fifth.
2. Data security**:** Maintaining the security aspects of data has always been a critical challenge for any technical adoption. Especially when data and information are shared with another party, security concerns come into picture automatically. In a cloud-based semiconductor

TABLE 6 Ranking of challenges in the adoption of cloud services in semiconductor industries

Rank 1:Network/internet availability	Rank 2:Data security	Rank 3: Integration of various services	Rank 4:Monitoring of data and services
Rank 5:Maintenance of computing performance	Rank 6:Liability	Rank 7:Power outage	Rank 8: Service interruption
Rank 9: Organizational change	Rank 10:Business complexity	Rank 11:Legal issues	Rank 12:Lack of awareness

Abbreviation: Ch, challenge.

TABLE 8 Cumulative percentage of eigenvalues

Component	Initial eigenvalues			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.777	31.475	31.475	2.524	21.037	21.037
2	1.479	12.325	43.800	2.114	17.615	38.652
3	1.275	10.629	54.429	1.649	13.744	52.396
4	1.033	8.608	63.037	1.277	10.641	63.037
5	.742	6.185	69.222			
6	.723	6.024	75.246			
7	.677	5.644	80.891			
8	.638	5.315	86.206			
9	.485	4.040	90.246			
10	.430	3.582	93.828			
11	.403	3.354	97.183			
12	.338	2.817	100.000			

Extraction method: principal component analysis.

Abbreviation: Ch, challenge.

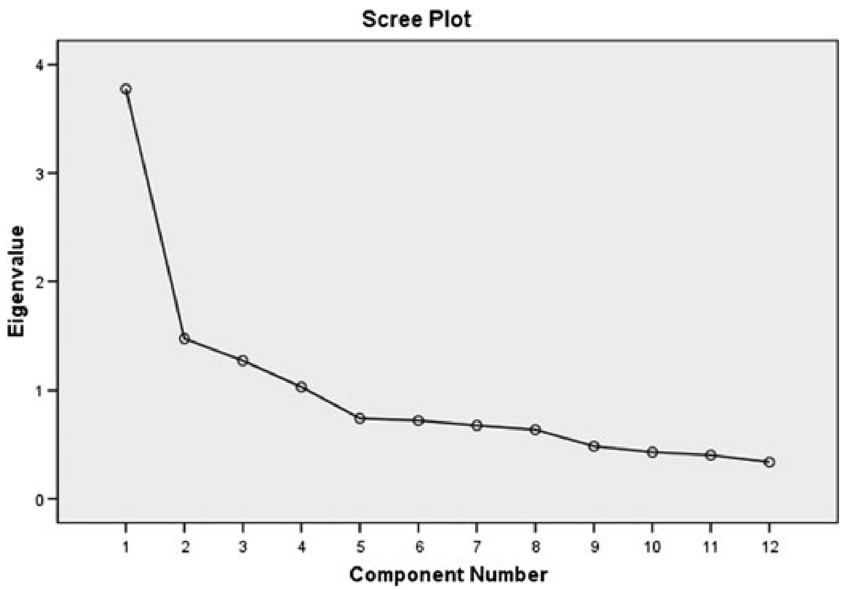

FIGURE 4 Scree plot

industry, all the crucial information of the industry are put up in the Web. The cloud service provider has access to the data related to fabrication and all other important processes of the semiconductor industry. The cloud service provider may not be unique for each semiconductor industry. One service provider may provide services to more than 1 industry. Therefore, there can be an issue of data mismanagement, and the important information may get leaked to the competitors. The survey respondents marked data security as the second ranked in our study.

3. Liability: In a cloud-based semiconductor industry, the critical data and information are shared through cloud service providers. Therefore, with the security issues, it also involves the issue of liability. It may also so happen that the data/critical information of a semiconductor industry are leaked because of some technical fault. In such situation, it will be a serious issue as to who will take responsibility. The cloud service provider will try to escape from taking responsibility in such situations. There may be several other instances when the liability issue may come into the picture. In our study, survey respondents marked this as a significant challenge.

4. Legal issues: Cloud computing will globalize the semiconductor industries. In that case, the cloud supplier may be located in 1 country but it caters to the need of semiconductor industries located in other different countries. Rules and regulations are likely to be different for different countries. Therefore, there may be difficulty in sharing and storing data and information for both

TABLE 9 Rotated component matrix[a]

	Component			
	1	2	3	4
Ch1: maintenance of computing performance	.256	.640	.008	.336
Ch2: data security	.642	.454	−.270	.066
Ch3: liability	.519	.515	−.219	.127
Ch4: legal issues	.420	−.031	.253	.575
Ch5: lack of awareness	−.114	.228	.124	.781
Ch6: service interruption	.661	.026	.158	.235
Ch7: integration of various services	.249	.642	.415	−.173
Ch8: monitoring of data and services	.059	.811	.211	.034
Ch9: network/Internet availability	.737	.162	.059	−.142
Ch10: power outage	.692	.035	.399	−.207
Ch11: organizational change	.252	.013	.700	.199
Ch12: business complexity	.024	.286	.745	.120

Extraction method: principal component analysis.

Rotation method: quartimax with Kaiser normalization.

[a] Rotation converged in 15 iterations.

Abbreviation: Ch, challenge.

cloud service providers and semiconductor industries. Several legal issues may hinder the process of cloud storage and access system. Survey respondents of our study also feel the same. They have marked this variable as a significant challenge. However, survey respondents feel that this variable will have less impact on the adoption of cloud services, as they have ranked it eleventh in our study. Possibly, the respondents feel that the cloud supplier and semiconductor industries will be able to sort out these rules and regulations before signing a contract, or even afterwards, when such an issue arises. Thus, the legal issues, although significant, may not turn out to be very critical in the process of adoption.

5. Lack of awareness: Till now, the semiconductor industries have worked independently. There was no support from cloud service providers. The cloud computing concept is relatively new. Therefore, the project managers and employees of both semiconductor industries and cloud are likely not to have adequate knowledge of different processes of each other. According to the survey respondents, this may be a critical challenge for adopting cloud services in a semiconductor industry. Although the respondents have marked this as a challenge, however, they have ranked this as the last. A possible reason for this observation is that the concerned managers and employees of both the organization could be adequately trained before the actual adoption of cloud services in a semiconductor industry. In today's world, there is no lack of resources to learn the different concepts involved in cloud computing and providing services. This is possibly the reason for which the respondents feel that the challenges "lack of awareness" will have least impact (among all the 12 challenges) on the process of adoption of cloud services in semiconductor industries, and so this challenge will have least criticality.
6. Service interruption: Several natural and man-made calamities may hamper the services provided by cloud computing. However, semiconductor industries need to have an uninterrupted 24/7 service availability from the cloud vendors. In case of breakdown in cloud services even for a short while, the production process in a semiconductor industry will be hampered. The workingness of the semiconductor industry may completely stop without access to cloud data and information. Rightly, the survey respondents in the present study marked this as a significant challenge in the adoption of cloud services in semiconductor industries.
7. Integration of various services: In cloud-based semiconductor industries, 2 different sectors need to work together for the best outcome. The cloud vendor needs to provide undisrupted services, and the semiconductor industry has to optimally use the services provided by the cloud vendor. As 2 completely different organizations will work in collaboration with each other, there is a strong need of service integration among them. In our study, the respondents have marked this as a significant challenge.
8. Monitoring of data and services: Semiconductor industries work with data and fabrication methods. They have to use different fabrication methods for the best devices. They cannot afford to lose any data or design. Semiconductor industries need to look for real-time integration of various results of their trial. On the other hand, cloud providers have to ensure real-time communication of data and services to the semiconductor industries. They need to monitor the data and results and make these available to the industry. In our study, the respondents marked this also as significant challenge.
9. Network/Internet availability: In our study this variable has been ranked as the most critical challenge by the survey respondents. In semiconductor industry, constant supply of data and results are necessary for developing and fabricating any device. For continuous support and services, the cloud service providers require 24/7 Internet availability. As we have collected data mostly from India, there is a lack of high speed Internet connection; the survey respondents marked this variable as most significant challenges. For developed countries, however, this may not seem to be very critical.
10. Power outage: Semiconductor industries require a constant power supply. One may argue that they usually have their own power backup system. But when they adopt the cloud services, they have to depend upon the cloud vendor for the flow of data and results. So the semiconductor industry needs to take care of uninterrupted power supply not only for their own organization but also for their cloud service provider. In our

TABLE 10 Factors extracted

Technical (Cloud supplier and semiconductor industry)	Managerial (Cloud supplier)	Organizational (Cloud supplier and semiconductor industry)	Managerial (Semiconductor industry)
Data security Liability Service interruption Network/Internet availability Power outage	Maintenance of computing performance Integration of various services Monitoring of data and services	Organizational change Business complexity	Legal issues Lack of awareness

study, the survey respondents marked this as a significant challenge.

11. Organizational change: There is a strong need for the organizational change for the cloud adoption in semiconductor industries. The structure needs to get shifted to a new collaborative model. This implies that the role of product managers will be changed. The present scenario of the industries is not at all suitable for adoption of cloud-based services. It is interesting to note that the survey respondents also feel the same, and so they consider the variable "Organizational change" as a significant challenge in the context of adoption of cloud services in semiconductor industries. However, the industries that are planning to adopt the cloud services have the information a priori that they will have to make some changes in allotment of the duties and responsibilities of their employees. The top management of a particular industry must approve the required changes, before they go for adoption of cloud services. Thus, the variable "Organizational change" would not be a critical issue. The present study based upon feedback collected from the respondents is in agreement of the same, because according to the study, this variable is ranked in the lower half of the list of challenges.
12. Business complexity: In the current practice, a semiconductor industry operates on its own. They are not depending upon any other industry for data, design, and methods. However, in cloud-based semiconductor industries, an industry will have to wait for the update from the cloud service provider. This implies that adoption of cloud-based services will create complexities in terms of data flow, in the business process of a semiconductor industry. Thus "business complexity" that is likely to arise in the functioning of an industry may cause some amount of hindrance to smooth functioning of a semiconductor industry. The present study marks these variables also as significant challenges towards adoption of cloud-based service in semiconductor industries.

Using the principal component analysis, we have extracted 4 components. These components have been named for the ease of use in an industry. The naming has been done based on the variables belonging to that component. Table 10 presents the name of those 4 components along with the variables within the components.

From Table 10, one may clearly observe that the component 1, which has been named as "Technical" challenges, consists of maintaining the security of the data, liability issues, interruption of services, network and Internet availability, and power outage problems. It may be noted that all the abovementioned variables are related to technical issues. These technical issues apply to both semiconductor industries and cloud service providers. Component 2, which consists of the challenges of maintaining the computing performance, integration of various services, and monitoring of data, has been named as "Managerial" challenges for cloud supplier. The challenges belonging to this component are more associated with the cloud service provider. These need to be handled by the cloud supplier. The third component consisting of the change in management of organizational structure and business complexity is related to both the semiconductor industry and the cloud supplier. This has been named as "Organizational" challenges. The fourth component, which consists of legal issues and lack of awareness, has been named as "Managerial" challenges for the semiconductor industries only. These can be taken care of by the top management. Proper training and preassessment of cloud adoption will remove the lack of awareness problem and legal aspects of the adoption.

The abovementioned components would be very helpful for both cloud supplier and semiconductor industries to handle the critical challenges, while adopting cloud-based services in semiconductor industries. Both the organizations should come up with proper planning and solutions based on the mentioned components, which capture the challenges in the adoption.

7 | SUMMARY AND CONCLUSION

In the present study, we have identified the critical challenges for the adoption of cloud services for semiconductor industries. Semiconductor industries are the fastest growing industries in the present world. Cloud computing has paved the way for data integration and storage to a new level. Semiconductor industries would be able to produce devices and products in a much faster and accurate way. However, these industries need to tackle the challenges with the help of cloud service providers, before the cloud adoption in the semiconductor industries. The critical challenges are identified in this study. This study will be very useful in process of adoption of cloud services in semiconductor industries.

However, since we have done a survey-based post facto analysis, there are certain limitations of this study. We have collected data primarily from Indian industries. While we had tried to distribute the survey from across the globe using e-mail and linkdin, most of the respondents in our study were from India. While some of the challenges like Internet availability and data security are important issues for developing countries, they may not be very critical for the developed nations. Semiconductor industries would like to have the solution to overcome these challenges for a successful adoption of cloud services.

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APPENDIX

SURVEY QUESTIONNAIRE:

Adoption of Cloud Services in Semiconductor Industries

Please mark your type of organization.

- Cloud Service Provider
- Semiconductor Industry
- Other:

Please mark the size of your organization. *

- Below 10
- 10 to 50
- 50 to 300
- 300 to 500
- 500 to 1000
- More than 1000

Please mark your experience in the above mentioned organization. *

- Less than 1 year
- 1 to 3 years
- 3 to 5 years
- 5 to 10 years
- More than 10 years

*** Please indicate your level of agreement in the following challenges for adoption of cloud services in semiconductor industries.**

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Maintenance of computing performance	☐	☐	☐	☐	☐
Data security	☐	☐	☐	☐	☐
Liability	☐	☐	☐	☐	☐
Legal issues	☐	☐	☐	☐	☐
Lack of awareness	☐	☐	☐	☐	☐
Service Interruption	☐	☐	☐	☐	☐
Integration of various services	☐	☐	☐	☐	☐
Monitoring of data and services	☐	☐	☐	☐	☐
Network/Internet availability	☐	☐	☐	☐	☐
Power outage	☐	☐	☐	☐	☐
Organizational change	☐	☐	☐	☐	☐
Business complexity	☐	☐	☐	☐	☐

You are invited to specify any additional comments regarding this study. (Optional)

***Kindly rate the ease of answering the questionnaire.**

- ☐ Very difficult
- ☐ Difficult
- ☐ Average
- ☐ Easy
- ☐ Very easy