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Research Paper

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A Prediction Model addressing the Changes and Challenges in Adopting SEaaS Model during COVID-19

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***Abstract*—** During this world-wide universal lockdown period, software companies are trying to find a possible solution to keep up their everyday activities. Software Engineering as a Service (SEaaS) will be able to provide support to the processes which they have been doing in the software development lifecycle (SDLC). Elaborately, SEaaS model has the ability to intelligently provision the design, development, testing, deployment and maintenance of the software.
Pre-COVID-19 and conventionally, software design and development happens within the corporate's boundary which always requires up-front investments, planning, procurement of infrastructure, purchase of software tools and space for development. During this COVID-19 lock-down and post this period, SEaaS will take care of the complete SDLC processes, and provision an end-to-end design and development model. This migration of on-campus development to off-campus (SEaaS cloud based) development is not without challenges and the changes that are needed at the SDLC process level.
This paper addresses the changes that will be needed and the challenges that need to be addressed when software development enterprises adopt their design and development processes and environment to SEaaS model. Also a machine learning model predicting the scope of SEaaS in the Off-Campus is built, scoring a significant fit in the prediction model.

***Keywords*—** Software Engineering, COVID-19, Software as a Service, Prediction Models

I. INTRODUCTION

Nobody ever predicted about his pandemic breakout. Software development companies were not ready to face this situation [1]. However, thanks to the cloud-based models such as Infrastructure as a Service (IaaS), Platform as a Service (Paas), Software as a Service (SaaS) provide services for software developing organizations, and the design and development team that works on software development projects [2]. Though much research and practice have been put into these areas of cloud based operations, there is another upcoming cloud-based model called Software Engineering as a Service (SEaaS). Though the initiation for this model has been manifested in 2013, it is quite challenging for the software development project teams and companies to get into this and operate reliably on the cloud.

More elaborately, SEaaS is seen as provisional platform in the cloud environment where the software engineering activities like requirement engineering, design and development, validations, deployment and maintenance of the deployed software are played in efficiently by the software organizations. It provides an end-to-end provisioning to execute all the software development life-cycle (SDLC) activities on a cloud environment [3]. Though this may sound a bit hard to take SEaaS as an everyday software development activity, there are possibilities to adopt it into the mainstream of software design, development and deployment.

Though this model of software development seems to be simple at first hand, they are not without many challenges, and these challenges can be met out with meticulous planning and necessary changes at the process level, task level, activities level, and even at micro-work level [4]. Connecting remotely to the EaaS instance using dumb terminals, SDLC activities can be carried out on the cloud with these connections made simultaneously by the stake-holders of the project – the development team, testing team, design team, managers, client teams etc [5]. This model of SEaaS breaks the traditional software developmental activities that involve people, processes, and technologies, and drives in a new environment in which the space constraints, storage constraints, infra-structure constraints, process limitations; communication barriers are removed making SEaaS simpler and efficient way for developing software in a better way – a way of the future.

Section II contains the pre-Covid scenarios in Software Development. Section III contains challenges needed in software development during this pandemic situation. Section IV contains the challenges faced by companies in adopting SEaaS. Section V contains the case studies of

organizations which adopted SEaaS and the results we obtained out of the experiments we conducted. Section VI contains the conclusion of the work describing the significance of the work.

II. PRE-COVID-19 SOFTWARE DEVELOPMENT SCENARIOS

Most of the software development organizations have evolved through the processes of CMM model and have a variety of hybrid processes customized for their organization and for each project. Every organizations were concerned about the wellbeing of their workforce and health care of every employee [6]. So project teams in an organization follow different sets of processes and micro processes that will suit their developmental activities well. Organizations too have tailor-made processes and micro processes that will suite them well in their day-to-day business operations. Both the project teams and the business teams depend most on their internal infrastructure mainly 1) for their own security and confidential reasons and 2) they have been into this model since the inception of the organization [1]. However, the new start-up companies that are into web-technologies, mobile app development, and solution providers for small-and-medium business companies have started to move to the cloud environment for want of infrastructures, platforms to operate and software tools for development. This is not SEaaS, because IaaS, PaaS and SaaS are provisioning different services with loose coupling between the activities of software engineering.

In the present context of software development, the entire process set can be divided into two:

1) On-campus development
2) Off-campus deployment

It is like building a car. Make all the raw materials come to the car manufacturer's site, make all the workers also to come to that site. The entire workforce of the car manufacturing company is into designing, building, testing, again rebuilding, refining the products (cars), and all the other activities like finance, budgeting, sales and marketing are all happening physically in the company. This we call as on-campus development. Note that a number of cars are manufactured within the project's deadline. Then the manufactured cars are moved to the market, showroom for display and then sales. The manufacture would not know who their customer would be. This later process is called off-campus deployment.

However, this same model is in operation, practiced in the software development companies, which doesn't suite well in this present era. An era where everything is becoming paperless is the good news. The raw materials are the requirements gathered, which can be collected by using a cloud based tools (Visual Trace Spec, Visure, ReQtest, IBM Rational tool,), analyzing and designing can be done using plenty of tools already available in the cloud (Google Analytics, Cloudcraft, Tencent, Lucidchart d-tools,), development – tools and technologies offered in cloud as SaaS (Kwatee for Agile Deployment, Azure for web applications, Visual Studio online, HTML5, Bootstrap, Atom, Zend studio, Cloud9 IDE etc), testing the built software – testing tools are available in the cloud (SOASTA CloudTest, LoadStorm, Nessus, Xamarin test cloud, Test collab, RSpec, Jasmine, Teaspoon etc) deployment and maintenance – absolutely possible with cloud – remote deployment and maintenance [7].

Figure 1. Cloud Platform

III. CHANGES NEEDED

In order to move the set of software engineering activities and processes from on-campus and off-campus to cloud requires some changes at the process level, physical level and metric level.

A. Changes in the SDLC processes:

This is the foremost change that challenges the process set itself. The 22 key process areas (KPA) that are already defined and have been in practice for the past 5 decades need changes in order to move software engineering as a service in cloud. The macro processes in KPA set doesn't need a change but the micro activities and tasks will need refinement in its execution at the granular level [8]. The KPAs are spread across the five phases of SDLC as shown in the figure 2.

Some of the processes at level-2, level-3 and level-5 are considered for this study of change. Here are some of the changes to be done in the key process areas so that the SDLC itself will be in cloud [3].

Requirements Gathering & Analysis (at level 2) - The aim of this process is to collect & analyze the system's requirements, formulate functional models and scenarios, define functionalities and validate all these requirements. Requirements collection is the only process that needs the requirements team and the client team to sit across in meetings to carry out effectively. Thanks to advancements in telecommunications and process automation tools. These days, people can be in any place and still communicate effectively through many rounds of video conference

meetings and skype meetings, all connected to the common cloud. Project demos and presentations are made in these modes of communications, more effectively and with less cost.

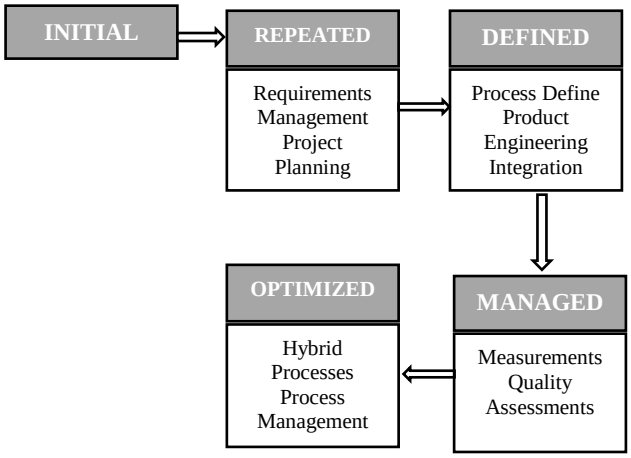

Figure 2. CMM & SDLC

Roger was enjoying his vacation with his family in a remote beach in India, but still connected to his team what was working in his office location. He was the head of the architect who played a vital role in defining the functional models and the system architecture for one of his latest software product for a client in Middle East. Without compromising on his day-to-day work, Roger was able to deliver his best. Thanks to the Cloud. Hence, this flexibility in the process of requirements gathering and analysis can reap good results.

Table 1. Change Parameters Solved in SEaaS

Parameter	Questions	Solved in SEaaS
Fitness:	Does the technology address the problem at hand, or is it being used for an unintended purpose?	The Technology solutions are derived based on cloud computing and distributed deployment
Maturity:	It's risky to use version 1.0 of anything. Both hardware and software companies are frequently pressed to release products before they are ready.	Any number of versions of software can be provisioned, because the protoypes or versions are ready for release in the cloud, with micro changes.
Provenance:	Small companies with ideas relying on technologies offered in cloud by big companies	Maturity of the work force in handling cloud based platforms and technologies
Support:	Instead of commercial products, can the open source software tools or technologies provide support?	24x7 support is possible because the product itself is developed in the cloud.
Reliability/availability/scalability:	Does the technology address the volume, scalability and availability?	Volume and Scalability are no questions in Cloud based solution. Availability is one that can be assured.
License and support costs:	How are the costs of licenses and proprietorship of software handled?	In SaaS and all these SEaaS, pay and use is the model without extra cost.

Technical Solution (engineering process area at maturity level 3) – This process focuses on evaluating and selecting solutions, developing detailed designs from the selected solutions, and implementing the designs and products or product components. These three important or core activities involve a number of teams participating actively 24x7. Presently these activities are carried out in a secured on-campus environment, which well controlled, highly monitored with state-of-the-art security enforced on hardware, software and documents, and this is costly. This model of on-campus software development is practiced by software giants, and it is successful till date. However, the start-ups and the middle-level business companies don't have funds to have massive infrastructure like these. Hence the solution to help them achieve their goals is 'put your processes in Cloud', and 'Let Cloud take care of it'.

A report according to Forbes [9] for evaluating and selecting technical software solutions is given in the following table, along with the feasibility of cloud based solution evaluation.

B. Change in the Development Environment

The software companies are spending countless money in their corporates' infrastructure, and the resources and processes offered to their software development teams are unimaginably comfortable and conducive. However, the productivity of a team or an individual involved in the

software development team seems to be not much appealing when compared to the money spent. For a 9-hour work schedule of a software developer/designer, the productivity hours is less than 50% of the time they spend in the projects. This keeps decreasing as years go by, and the teams sometimes need a change in projects or need a recreation, and sometimes even leave the company.

Table 2. SDLC phases and Provisioned SaaS Tools

SDLC Phases	SaaS provisioned in Cloud	People Responsible
Requirements Phase	Visual Trace Spec, Visure, ReQtest, IBM Rational tool,	System Architects, System Analysts, Business Analysts
Analyze and System Design	Cloudcraft, Tencent, Lucidchart d-tools,	System Architects, Design Engineers, Project leads,
Software Construction	Kwatee for Agile Deployment, Azure for web applications, Visual Studio online, HTML5, Bootstrap, Atom, Zend studio, Cloud9 IDE etc	Project Leads, Team Leads, Software Engineers, Associate Software Engineers
Testing and Validation	SOASTA CloudTest, LoadStorm, Nessus, Xamarin test cloud, Test collab, RSpec, Jasmine, Teaspoon etc	Project Leads, Project Test team leads, Test Engineers
Deployment	Deployment in remote cloud	System Architects, Project leads etc.

Yes, the solution is to provide him a remote access to his working platform. During the lockdown of companies, corporates, and research institutions, the working teams are connected through several cloud media offered by ZOOM, Google, Microsoft and many other service providers. But these are mainly meant for communication. Are there tools to make development happen remotely? Yes. There are plenty of Softwares as a Service (SaaS) offered in several Cloud services [10]. The following table gives a list of softwares available as SaaS in the cloud, and they cover exclusively all the phases in SDLC.

If there are a plenty of SaaS provisioned in a Cloud, there couldn't be a limitation for a development team to work from remote login terminal to one of the clouds and perform his everyday activities of the project team [11]. This can be made effective when an organization can work on redefining the SDLC processes. This provides almost instant access to the software and development environments, by providing multi-tenancy of the virtualized servers and other IT infrastructure. Specifically, PaaS (Platform-as-a-Service), the development platform environment in the cloud, encourages use of Agile methodologies. Agile and PaaS together add great value to the SDLC processes [12]. They help to reduce costs for enterprises in the long run and help in increasing developer productivity at the same time.

IV. CHALLENGES IN ADOPTING SEAAS

A. Real-time Environment Parameters

SEaaS demands several real-time environment parameters that need to be addressed at large, like security, customizable space, on demand tools, and intelligent monitoring systems. Cloud based development environment has always been part of our on-campus activity, but shifting our gears to rely completely on a cloud-based environment as a service provider that would provision all the SDLC activities is a quite big challenge, and a costly one too [3].

Security: Files, application program codes, databases, data, email are some of the most important entities that would need utmost security. While sharing these development parameters onto a third-party cloud will remain as a security challenge [13]

Customizable space: Storage space and working space for all projects onto a service provider's platform will require intense space management systems. While most of the companies are dealing with voluminous bigdata having their sources from different repositories, space provisioning will remain a challenge. Sensitive, copyrighted codes of algorithms and executable libraries for the companies' projects and their own products will need a much sensitive data storage provisioning [14].

On-Demand Tools: When software tools are offered as SaaS, some of the tools like IBM rational tools, Azure, Test Cloud, LoadRunner are still are available on-demand. This will remain a challenge when the platforms of offering are not available when required by the remotely connecting project team.

Intelligent Monitoring System: Monitoring technical parameters, processes and people, is going to be a very demanding task when software engineering activities are going onto the cloud as a service [10]. We would need intelligent monitory systems that would learn, measure and control the engineering storage and execution parameters, activities and processes that would involve people, and proactively take decisions to keep these parameters in check.

B. On-Campus and Off-Campus Integration

As already discussed in section 2, on-campus development and off-campus deployment is part of the SDLC. However, changing this methodology will be a challenge in the functional part of the organization. During these days of the COVID pandemic, almost all of the software companies have opted to move to off-campus development, as they have no other choice. This is the experimentation time for the software projects to be moved to off-line development.

Though communication remains a greater challenge in this move, companies are finding it worth keep their workforce work remotely. The biggest challenge would be to integrate the works done or monitoring and having the work done from the geographically disconnected workforce. However, companies are trying hard to find solutions for this challenge. SEaaS is slowly picking pace.

C. Ramping-up the Existing EaaS

In addition to IaaS, Saas, and PaaS, Engineering as a Service (EaaS) is a possible solution to the shifting of software engineering activities as a service. EaaS provides three modules: provisioning, execution and process. While provisioning deals with creating an environment for the SDLC activities by setting up input parameters through a wizard based interfaces, estimate all the necessary boundaries for SDLC, and provide the estimated environments for the project. Execution module is more focused on the execution of all the phases in SDLC, like capturing SRSs, architecture and system modelling, IDEs, versioning, and testing [5].

Though EaaS is a preferred solution to the changes and the challenges of SEaaS, scaling this from start-ups to multi-national, multi-project holding companies is going to be another challenge. If only bigger companies can own their own cloud infrastructure, the start-ups would survive this SEaaS environment.

V. Case Study: Adopting SEaaS is a Possibility

This study that has been initiated since the April 2020, when the entire worlds countries, the US, the European countries, India, and the Middle-east countries started to experience the impact of the COVID-19, and the governments forced to lockdown companies, businesses and other avenues of work. The companies and its workers were not able to respond to the situation immediately, but after 20 days, they were able to resume work by using their existing online development tools, available in their cloud service provisions.

Since everything seems to be theory so far, prior to the pandemic period in India and in the whole world as well, we contemplated to conduct an online survey among a few software development companies in Chennai, India, Muscat, Oman and North Carolina, US. When this proposed SEaaS model is explained to the companies and asked them to try implement a few of them in their companies, we got certain metric values, which we thought would be relevant in concluding this paper.

We collected the following metric values:

1) Projects that used IaaS, PaaS, SaasS for their routine developmental activities.
2) Projects that need to be worked in On-Campus and Off-Campus
3) Types of Operations involved
4) Category of Workers

The workers are categorized into five types based on their operations and responsibilities in the project. The types of operations are integrations, provisioning, designing, coding, testing, finances, operations, human resources and quality. We collected data from 5 companies in Chennai, one each in Muscat and North Carolina. The companies did not reveal all the projects that are live, but shared only those that are non-client sensitive. Most of the projects are involved in this study are in-house and product based, and a very few solution-based.

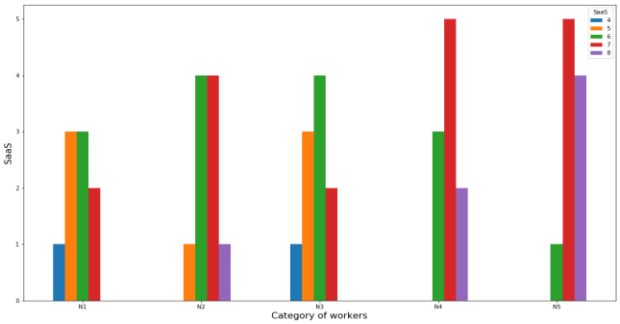

Figure 3. No. of Off-Campus projects using SaaS

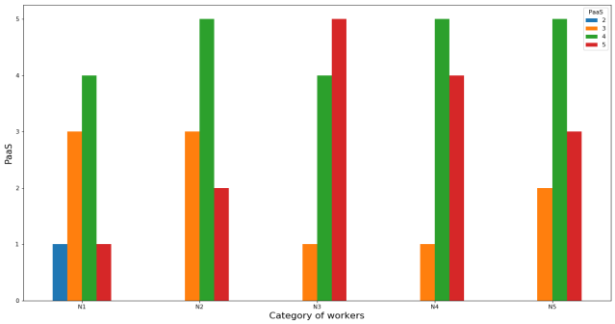

Figure 4. No. of Off-Campus projects using PaaS

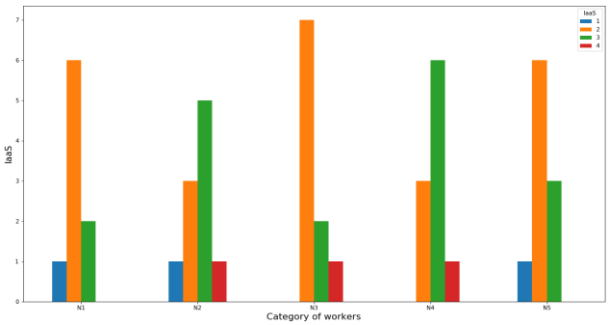

Figure 5. No. of Off-Campus projects using IaaS

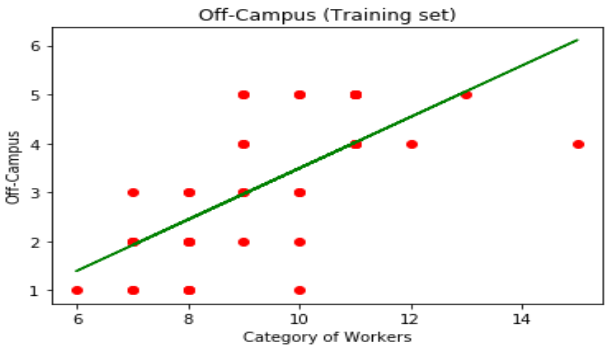

Figure 6 (a). Training set for Off-Campus Works

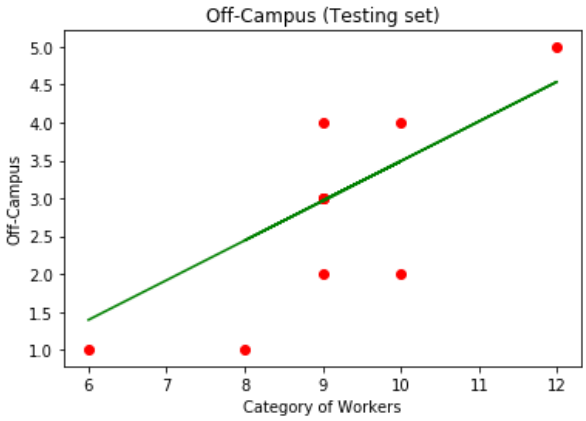

Figure 6 (b). Testing set for Off-Campus Works

Figure 3, Figure 4, and Figure 5 gives the status of category of users involved in projects that would require using IaaS, PaaS and SaaS. Higher number Off-Campus projects in the N4 and N5 and very less N2 category of workers are using SaaS while moderate number of N1, N2, and also N3 are using SaaS for their projects from remote locations. Almost all the categories of workers except N1 are involved in using PaaS for their projects who work Off-Campus. Whereas in IaaS case, all the categories of workers are involved in only 2 or 3 Off-Campus projects, against the maximum number of projects are 15. Figuratively, comparing SaaS, PaaS, IaaS involvement in the projects, we get 60%, 45% and 17% respectively, of workers are involved in the remotely connecting process of the SEaaS model.

We also tried to build a linear regression model for this case study. It was quite interesting to note that we got the Test Score to be 90% and the Train Score to be 81%, which indicates that the predictions forecast on Off-Campus projects were more accurate. Figure 6 (a) and (b) show the training set and test set scatter plot for the Off-Campus predictions.

This helped us to conclude that the way in which the companies are now using the SaaS, PaaS and IaaS in their projects connecting remotely to these services, the forecast of the future working model of these companies tend to move towards

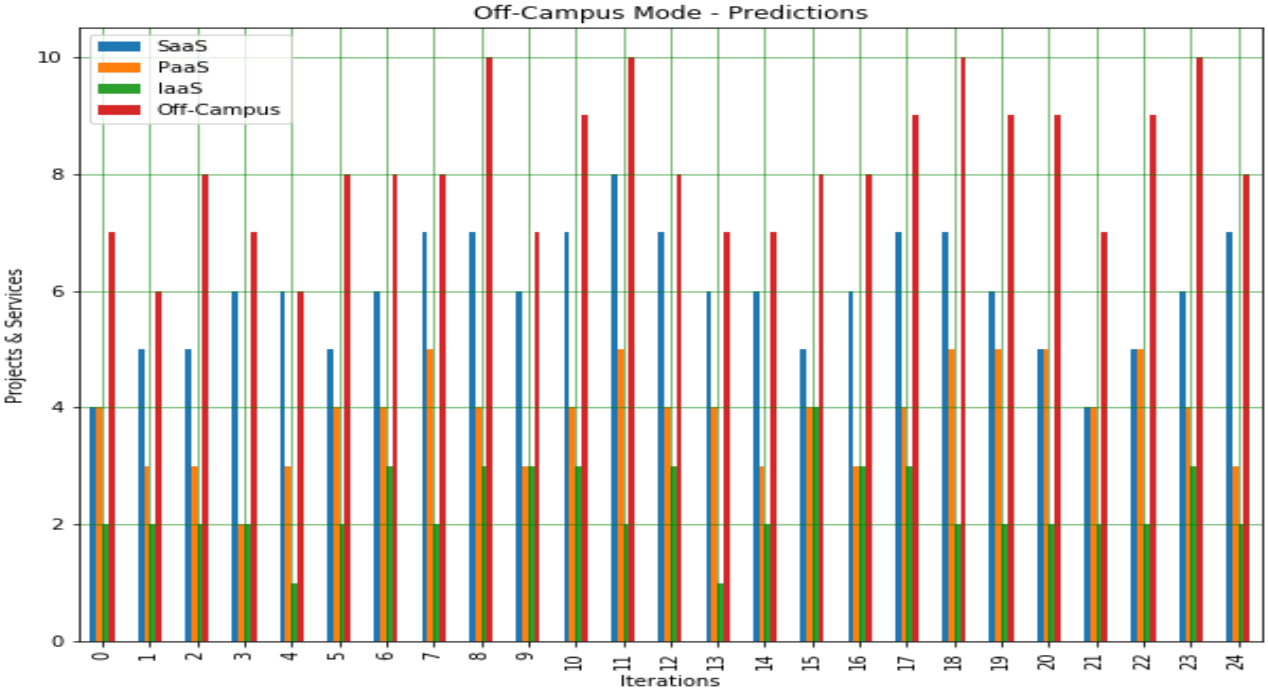

Figure 7. Predictions of the Off-Campus working mode tending to SEaaS

SEaaS. Figure 7 shows the prediction values of the possibility of adopting to SEaaS. We tried to build a machine learning model to predict the tendency towards shifting to SEaaS in terms of the usage of SaaS, PaaS and IaaS using in the Off-Campus mode. We did not take into consideration the On-Campus mode, as it was a regular mode of work.

The training set of the data were from the companies that are working on live projects for the past 5 months in the US, 3 months in Muscat and 4 months in Chennai.

The predictions that were made using this model helped us and the management of the three companies to decide on the how long we will be able to run along with this off-campus mode of work culture, using the available SEaaS tools and models that we have proposed in this paper. Figure 7, predicted that off-line SEaaS based work environment will be the style of working in companies that are into software development and software services.

VI. CONCLUSION

This research work is a quick work carried out at the outset of this pandemic COVID-19 attack. This universal situation has never been imagined by the software development companies world-wide. While some multi-national companies were able to sustain it projects using one or the other war-footing models, there are still many companies struggling to cope with this situation where workers couldn't go to their on-campus development [15]. Hence we proposed a software development model which required changes in their SDLC processes and there were challenges to be addressed, and we collectively lead the way to Software Engineering as a Service (SEaaS) [16].

Two major changes were proposed in this work and two major challenges were addressed to the software companies to move towards an off-campus or remote working model, but solely based on the EaaS as the platform where SaaS, PaaS and IaaS services are provisioned in a bundle as SEaaS [17]. We also worked a bunch of companies in Chennai (India), Muscat (Oman), and North Carolina (USA) and collected data from them. The data represented five categories of workers working on three service types on a maximum of 15 projects, where some are on-campus and others are off-campus. For this work we considered only the off-campus projects and other related parameters, and tried to build a machine learning model to predict the tendency of the companies and the projects to move towards SEaaS. The results were significant that the predictions showed 91% accuracy in forecasting the off-campus mode of working among five categories of workers working on nine different operational domains.

This work gave us directions to focus more on the implementation of the changes and the challenges successfully addressed by the companies while they make a move to SEaaS. The main focus would what processes needs tailoring, and what new processes emerged and how we could build a prediction model that would give us an insight on the successful progress of the implemented SEaaS based software development model.

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