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CLOUD COMPUTING IN CONSTRUCTION INDUSTRY: USE CASE, BENEFITS AND CHALLENGES.

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Motivation of the paper:

Construction industry is one of the most investment intensive and data intensive industries as heterogeneous data is continuously generated as the project progresses. This data needs to be stored for the overall project coordination, elsewhere the holistic view of data often leads to wrong decisions that could delay the project.

Traditionally, this was done by installing servers and in-house data houses, which requires huge investment and maintenance costs. Cloud computing technology provides affordable and scalable computing thus reducing the costs one has to go through. For this to happen, researchers must expose the potential benefits of the cloud computing technology to the construction practitioners.

The need to fill in the details and the knowledge gap lead to this research to be done and thus this paper be written.

Objective of the paper:

The objective of this paper is to bring to the fore, current and future application areas of cloud computing in the construction industry, along with throwing light on different barriers the construction industry has to face for broader adoption of cloud computing and ways to overcome these barriers using different strategies.

Major contribution:

Existing literature shows that there is no state-of-the-art information and survey doing the analysis of cloud computing in the construction industry. So, the contribution of the study is:

- This study analyses and categorises different use case scenarios as to how this emerging technology can be applied in the context of the construction industry.
- This study also throws light upon different challenges militating against the broader and wider adoption of this technology.
- Relevant strategies and insights have been provided to overcome these barriers, thus channelling a path for construction practitioners and researchers.

Description of the proposed approach:

The major proposed approaches and their use cases (of cloud computing) that are identified after this survey which can be used in construction industry are:

1. Cloud computing for construction waste minimisation:

   The wastage of resources throughout the lifetime of a building is huge and these can be minimised by a Cloud Computing Information System (CCIS) collaborative tool to ameliorate productivity deterioration arising from lack of coordination among parties involved in the precast construction.

2. Cloud computing for safe construction:

   Construction sites are often prone to accidents due to the huge equipment and unforeseen circumstances. The risk is even increased by a lack of access to real time safety information to provide predictive, quantitative, and qualitative measures allowing the identification, correlation, and elimination of hazards.Cloud technologies are thus being employed to provide timely access to safety information and in turn resulting in improved safety performance of construction sites.

3. Cloud computing for energy Management in Construction:

   Since deploying an in-house data centre would need lot of energy and under utilisation of resources, opting for cloud computing would help in reducing the amount of energy used. The Saas,Paas and Iaas provided by cloud can be used to simulate different parametric models for reducing the energy requirements of a building.

4. Cloud computing in supply chain Management in Construction

   The existing uncoordinated traditional material supply in construction sites usually resulted in supply gap leading to delay in projects. Thus, the Paas of CC can be used to track material movement on construction site and thus help in better management.

5. Cloud computing for Project Management informatics

The construction industry is characterised with communication and coordination problems culminating in low construction quality. Thus, a public SaaS cloud could be deployed to formalize the transfer of knowledge among local construction companies to improve the construction project. Also, Employed federated clouds can be deployed to coordinate multi-site construction enabling varied individuals and organizations on multiple projects and in varied locations to exchange information and data for better management. A brief overview of advantages of cloud are:

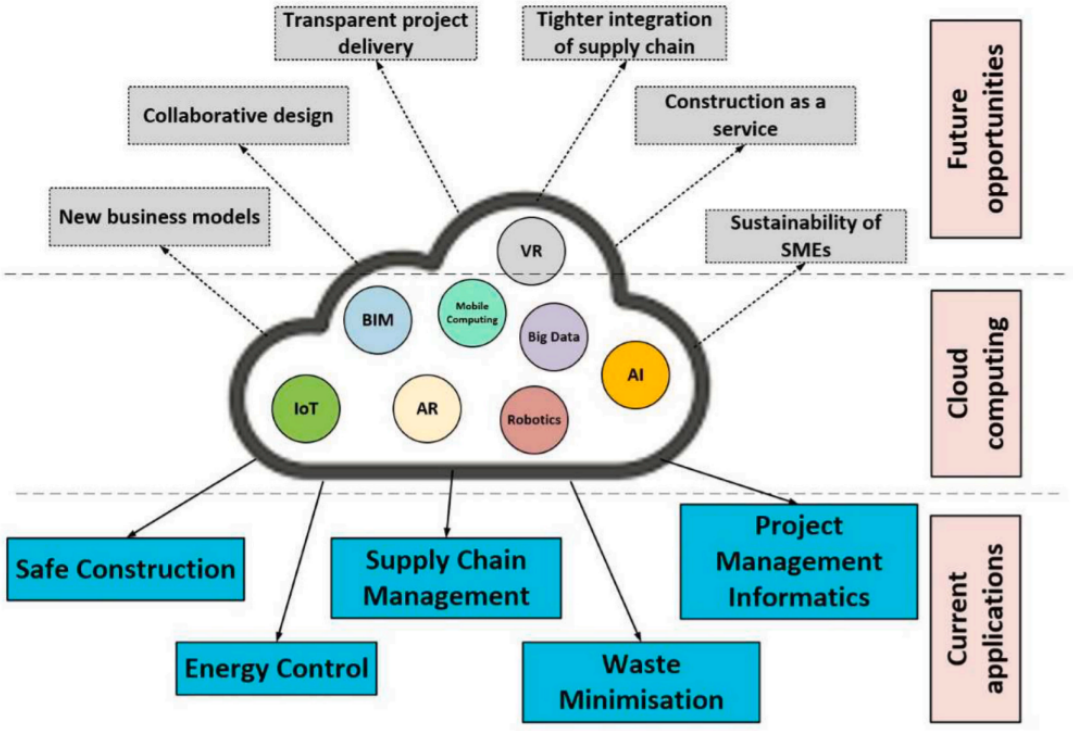


Fig. 8. Existing and Future Applications of Cloud Computing in Construction Industry.

All the other areas in which cloud could be helpful are discussed in the strengths section of this report.

Discussion of the experimental testbed and results:

The experiment done in the paper was to do an extensive review of the literature to find the relevance of cloud computing in the context of the construction industry. The steps involved were:

- Paper Selection method : Papers from SCOPUS, Google Scholar and Science Direct were selected and the papers from 2009 to 2019 were selected based on different inclusion and exclusion criterias specified.
- Selected papers then underwent a more focused title and abstract review to filter out the irrelevant papers.

The architecture is as follows:

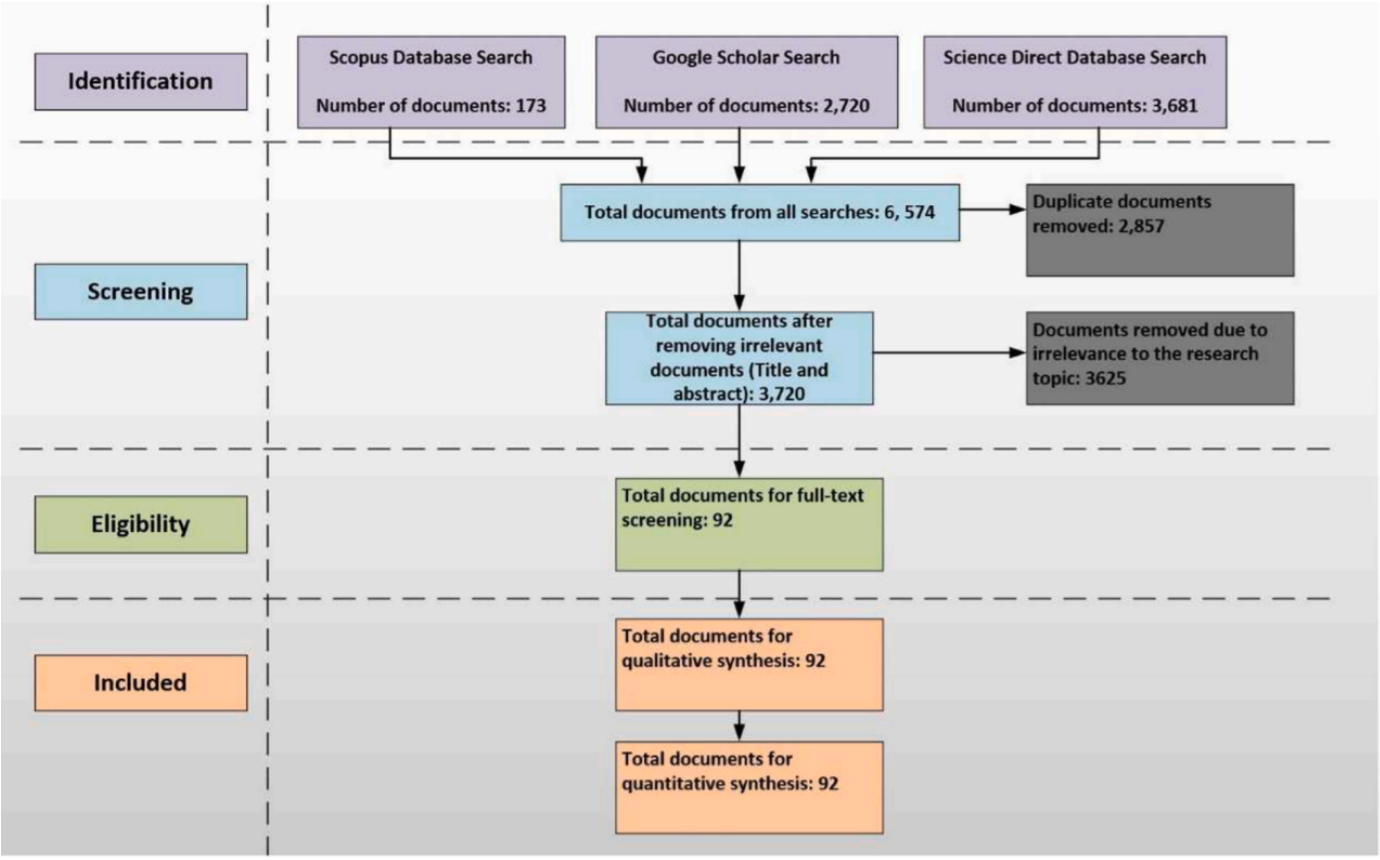


Fig. 4. Flowchart of the Systematic Review Process.

The following gives us an idea as to how different countries are doing research in using cloud comepuing in construction industry:

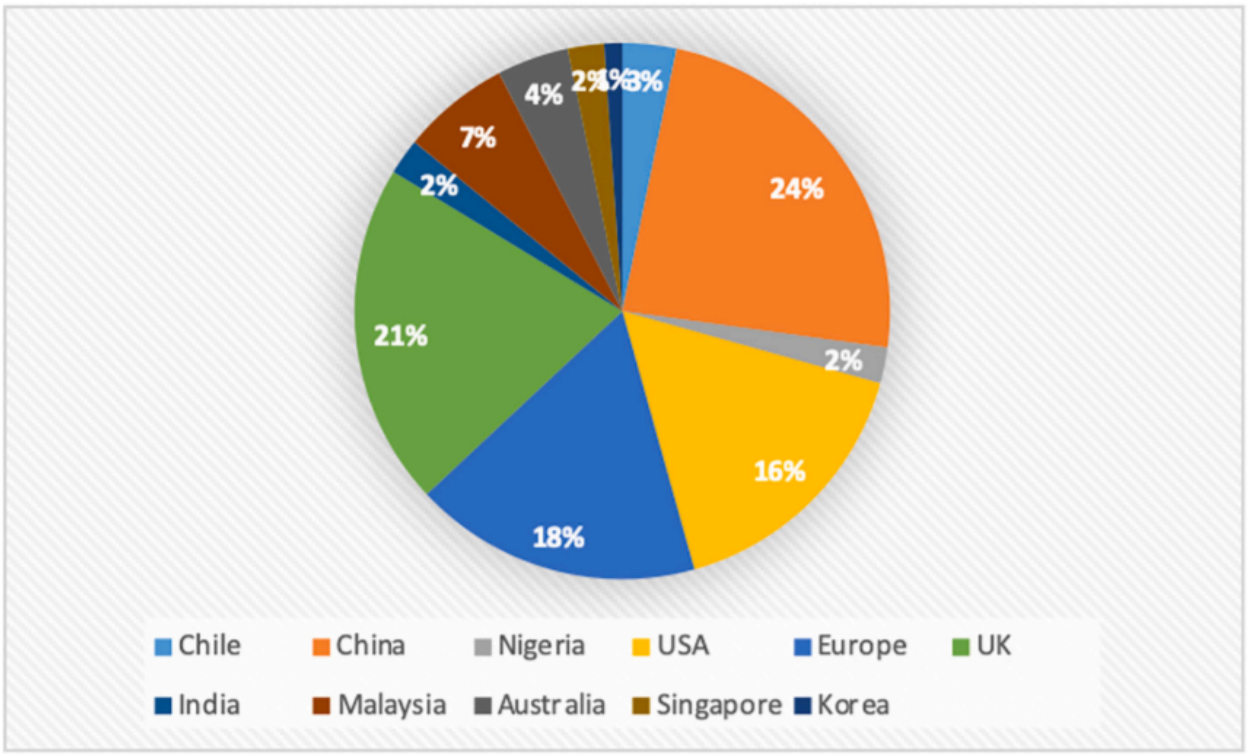
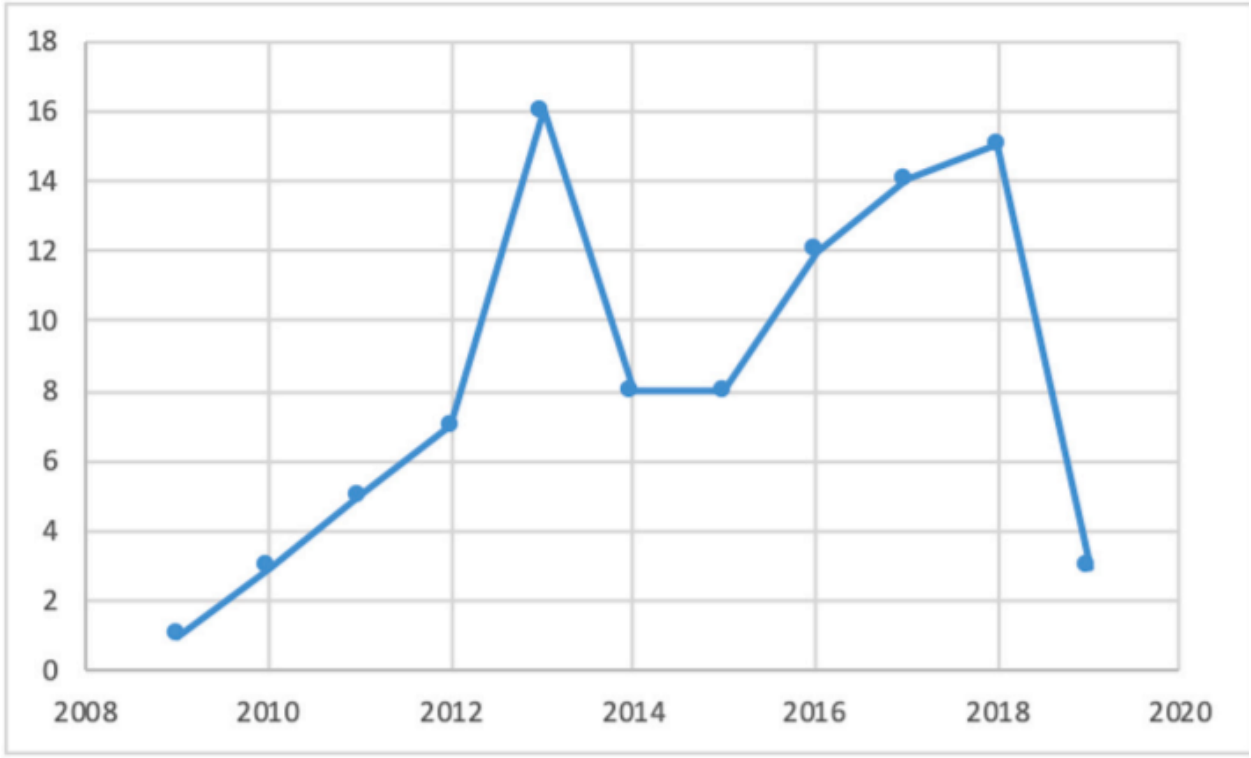


Fig. 5. Publications per Territory.

The following graph shows the research growth according to years:



Since experimentation was not feasible in the early years but was required for papers from 2015, This accounts for the drop in 2014 that gradually picked up again in 2015. This upward trend reflects the global interest of the research community in cloud computing and construction which is a promising sign.

Strengths:

This is the first of its kind study, viewing construction industry from the inception of cloud computing technology to the present.The extensive survey and research of literature done in this paper, which wasn't available all this time show that the need for cloud computing seems very much elegant in the construction industry due to the following benefits it has to offer:

1. Economic benefits:

   Since the construction companies have cost as a significant barrier, they are seeking new ways to drive down infrastructure and operational costs. Since payment will only be for actual consumption, the cloud computing technology provides increased agility for the construction by the elimination of ownership and operational costs.

2. On-demand scalability of computing resources:

   Cloud computing enables a construction company to purchase IT resources as services dictated by the specific requirement at that particular period on a construction project. A short-term need for a higher capacity infrastructure that necessitates tying down capitals on computing facilities is no more economically viable.

3. Secured platform:

   There is virtually no SME in the construction sector that can afford the level of data security found in the cloud in their in-house infrastructure.It is also very costly for construction companies to implement system availability on in-house computing infrastructure that could to match up with the 99.99% SLA (Service Level Agreement) and uptime provided by cloud service providers.

4. Massive storage:

   Storing construction data on site has been a problem as a result of the volume and the required hardware infrastructure for such on-site storage. Additionally, storing data on the site requires physical access, whereas with cloud storage, data can be remotely stored and retrieved with no limitation to space and time.

5. Facilitating collaborative practice:

   Construction projects are executed by several project teams, with different business reporting models.The scattered data are not readily available for timely and critical decision-making by the stakeholders in the industry. Cloud provides a central repository for construction data for-end-to-end solution that improves the productivity and

organisation of the construction industry.

Limitations:

The challenges in implementing cloud in construction industry:

1. Latency:

   Cloud adoption in construction may not guarantee acceptable transfer rate and response time required for some time sensitive construction applications. This could either be a software issue or network problem. This could lead to wrong decisions taken or delay in the project due to the downtime of a service provider.

2. Trust, data privacy and security:

   The anticipated vulnerability in the adoption of cloud technology is increasing due to the increasing fluidity of the security perimeter. Business partners are usually unwilling to give their private and commercial information such as project cost to a third-party service provider. Storing construction design and financial information in shared resources understandably gives concern to construction industry and the stake holders.

3. Data availability:

   A cloud provider may have cause to shut down their resources unexpectedly. The building data thus becomes unavailable, due to which the construction comes to a halt or ends up taking wrong decisions. It concerns more so if this happens at the middle of a construction project when important design data or decisions have to be taken.

4. Data governance:

   Construction projects involve many professionals, there is the need to spell out the contractual relationship between stakeholders. This is critical since the data is being contributed, it may be regarded as being owned by all. Much of the sensitive information is to be hidden from different people, else would be accessed by all the people involved.

5. Poor broadband connectivity of construction sites:

   Access to cloud services is primarily over the internet, hence, to maximise the benefit of cloud solution in the construction site, internet connectivity must be available every time. Project sites at times might be an underdeveloped area or a rural area usually with low or no internet connectivity, which poses as a serious threat considering the reliability.

6. Cost implication of long-term use:

   There could be substantial high cost of renting high-end resources such as GPUs for performing project analytics and machine learning tasks. It might be necessary for individual construction company to perform personalised cost analysis of longterm use of

the various cloud deployment models before moving into cloud.

7. High chances for scoring dark data:

   Dark data are data that are acquired but are not further processed or analysed for any meaningful insight. This often happens as the data producing rate is much higher than the computational power. The energy consumed in storing and maintaining dark data are becoming significant, as appreciable amount of money is being spent in storing irrelevant data in construction sites.