Towards Cloud Based Collaborative Design – Analysis in Digital PLM Environment

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Abstract. This paper proposes a cloud-based PLM methodology to carry out collaborative design by implementing industrial scenario representing realistic collaboration among all the stake holders. In a world of advancing information technology and more than ever demand in the requirement of spatially inter connected collaborative work space, cloud based generic design process methodology seems to be a viable option. However, it has been noticed that there has been little effort directed towards Cloud Based Design (CBD). It is a widely accepted fact that nearly 80% of the manufacturing cost of a product is determined by its design process and hence targeting the very same process of PLM is the prime focus in this paper. With an increase in the complexity of products along with the squeezed budget across all industries, there has been a growing demand to have cross company collaboration. To deal with such a complex requirement of communication and coordination between all the players in the design process, this paper links the field of collaborative design and cloud computing to propose paradigm-based solution to cater generic design process. This paper showcases the main advantages when CBD data and legacy CAD data are used to create a unified digital model to achieve a true cross company collaboration by the means of Cloud Based Collaborative Design (CBCD) methodology.

Keywords: Cloud · Collaborative design · PLM · Interactive design
Legacy users

1 Introduction

The globalization is gripping the world much more quickly and this has induced new models of industries where fierce competition, addition of disruptive technologies, and inter connected collaborative workspace are becoming a reality. Not so long ago, Cloud Computing was limited to only some specific industries, but now cloud computing has emerged as one of the major enablers for the product development industries by transforming the traditional design and development process by aligning product innovation with business strategy and has created big collaborating network of geographically dispersed industries. As 80% of the manufacturing cost comes from the

Published by Springer Nature Switzerland AG 2018.
P. Chiabert et al. (Eds.): PLM 2018, IFIP AICT 540, pp. 261–270, 2018.
https://doi.org/10.1007/978-3-030-01614-2_24

design process of a product [1], it is evident that coupling cloud computing with design process was a viable option. Based on the same reasons, many researchers have pursued Cloud Based Design (CBD) and even merged it with another similar concept called Cloud Based Manufacturing (CBM). There is no indication of the existence of ideal CBD systems which represent a model where collaboration happening between legacy systems and the new CBD users, thus making it impossible to have a cross company collaboration between Small and Medium-sized Enterprises (SMEs) and big enterprises. This paper will focus on Cloud based Collaborative Design (CBCD) and explore its main constituents, merits over other systems. This paper first starts with literature review about importance of cloud, evolution of design. This is followed by CBCD methodology and case study to test it. The paper ends up with results, discussion, conclusion and future work about CBCD systems.

2 Literature Review

The literature review focusses on the main constituents of CBCD system that is cloud, design and collaboration and communication to explore their importance in the methodology and how they impact the design process holistically.

2.1 Cloud - Highlights

As per the hype cycle proposed by Gartner in 2017 [2], different portions of cloud computing fall in the 5 categories, right from “Innovation trigger” to the phase “Plateau of productivity” where Software as a Service (SaaS) falls in the latter category, thus showing a great opportunity to be explored as also visible in the hype cycle proposed by Gartner [3]. From the perspective of design, cloud allows to access, review and modify design easily from geographically diverse locations, allows data continuity and fluidity based on cloud-based PLM methodology, secured exchange of knowledge management and data exchanges and real time collaboration for true concurrent design engineering. In the same context, SaaS which has embarked upon a journey of revolutionizing the sector of CBDM (Cloud Based Design and Manufacturing) has been able to provide customers licensing combined with maintenance and monitoring, management of IT infrastructure related to cloud and a network of multitenant data centers to ensure maximum performances and protection from emerging security threats. In the recent times, cloud computing paradigms have received a lot of excitement from the world but despite having such reputation (IT buzzword); many industries have not explored its full potential which offers a space of research to be done.

2.2 Design – from Past to Future

In this section, the past is referred as traditional design process, present is the conventional computer aided design tools/systems and the future is CBD. As per the literature survey, many descriptive models of design process have been proposed over the years and among them, the famous ones were proposed by Pahl and Beitz that consists of 4 main design phases: planning & clarifying the tasks, conceptual design, embodiment design and detailed design [4] in a linear chain. Most of the approaches of design process developed afterwards in form of extension or modification are found to be related to the fundamental approach of Pahl and Beitz [5]. But when it comes to concurrent engineering there is a scope of improvement in the process and hence, this paper proposes a generic design process with steps and sub steps, which works for a cross company collaboration involving legacy and CBD users.

The IT advancements over the period introduced CAD systems which can be hosted on cloud, allows multi-tenancy, SaaS based pay per use model among many other benefits of Cloud based Design thus providing a unique experience of distributed and collaborative design [6] and is now being experienced across all the industries who have completely migrated all their data. However, there are ample of industries who carry out design work in file based legacy CAD systems (Dassault Systemes CATIA V5, PTC Creo™etc. [7]) and hesitate to migrate into the cloud platform because of difficulty in migration in terms of cost, time and technical difficulties among many other reasons. Thus, a big population of legacy system users miss out from the advantages a CBCD system has to offer. Therefore, to have a cross company collaboration among all the industries, it is necessary to connect legacy systems users to the cloud-based software while maintaining their data in file based legacy format.

In general, design process has been claimed by many is composed of three sets of group functions such as the first group that involves designers taking technical decisions followed by the second group that considers design process as workflow with task dependencies and product information exchange comprises of actors associated with operation and project management and finally the third group that evaluate the meaning of collaborative designs as people accessing product data and sharing the design information comes from the group of CAD and CAE functional areas [8]. An effective collaboration among them is important to have fluidity in the design process. Even with the addition of CAD system, the problem of communication persisted because engineers are still communicating with each other via emails and sharing data via multiple resources like pen-drives for bigger files and small files via email. It further gets complicated by the CAD/CAM/CAE systems which are standalone system and are required to be installed individually on premise [9]. All these different applications hosted by different providers require maintenance and operational cost which turns out to be higher as compared to the CBD systems when compared the holistically [9]. The major thing which is found to be missing in CBD process is the lack of common platform where all the activities of working and sharing can be carried out including architecture of product, BOM management etc. to have an effective and efficient communication and collaboration. Additionally, many collaborations can be carried out in web-based apps instead of native applications (requires installation on system) and this has been leveraged in the proposed methodology where certain activities have been moved to web based applications from the native applications. To achieve a unified digital model comprising of legacy users and cloud users, it becomes clear that new forms of apps need to be developed to move more activities into the web, whose functionalities can be accessible from mobile devices. One of the example of current process of design activity includes problems like CBD and legacy users can't merge the data or legacy users can't simulate data in a CBD software and the future where a unified model is used by all the companies involved in design process can be seen in the Fig. 1. Therefore, hence this paper aims to target this aspect by envisaging Cloud Based Collaborative Design (CBCD) to investigate how cross company collaboration can be carried out where design process uses a unified digital model concept in a design process and discusses the learning outcomes of this new methodology to support collaboration between large enterprises and SMEs by bringing CBD and legacy users together.

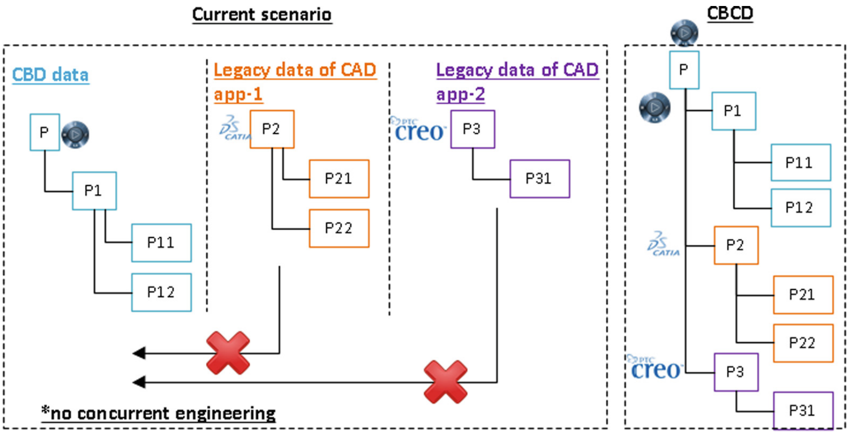

Fig. 1. Product architecture in current scenario vs CBCD [7]

3 Cloud Based Collaborative Design (CBCD)

CBCD is evolved from the best practices of CBD systems along with an addition of legacy system users in the process as discussed in the following sections

3.1 CBD Systems

Many definitions of CBD have been proposed in the past and one of such widely circulated in many papers "Cloud-Based Design (CBD) refers to a networked design model that leverages cloud computing, service-oriented architecture (SOA), Web 2.0 (e.g., social network sites), and semantic web technologies to support cloud-based engineering design services in distributed and collaborative environments" [10]. There is very less literature available which specifically study the characteristics and key constituents of CBD system except few like Andreadis, et al. [11], who in their work analyzed the contribution of collaborative design in the era of cloud computing but it doesn't follow design process for analysis and rather consider one-stage process to focus more on CBDM in totality. In most of the case CBD becomes a sub-part of CBDM where only certain aspects like early design stages or only data created in CBD are considered and thus loses their importance during adoption. It can be said that CBD has not been explored a lot even though design process is responsible for majority of the cost incurred in product development.

3.2 Conceptual CBCD Process Methodology

In CBCD environment, multiple stakeholders can be involved to do design and development activities like project manager, design engineer etc. of both Original Equipment Manufacturer (OEM) and suppliers. Taking in into account, all the problems identified in the literature review, CBCD design methodology for a cross company collaboration is envisaged as shown in Fig. 2. It consists of 4 stages where at each stage, sub steps involved are as shown in the series of images.

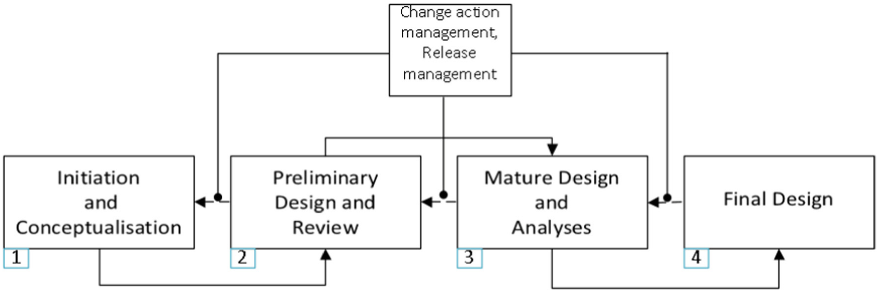

Fig. 2. Proposed CBCD methodology

The process starts with Initiation and conceptualization (Fig. 3) where project manager uses the historical data, CR (customer requirement), market analysis, RFQ etc. to create a project scope, roles required, estimated time and cost. This is followed by creation of collaborative space for cross company collaboration, assignment of tasks, roles. At this point component designer role is offered to legacy user to connect with the collaborative process on cloud. The first mockup in form of sketch or adding annotation to an existed similar product in cloud is added to start conceptualization. At the end of this stage, a mockup (digital or file based) and comments are shared to start the preliminary design and review phase. The process has been simplified by taking some activities which were possible only on system installed software/native applications to the web-based applications which can be accessible by mobile devices as represented by yellow boxes. Cloud user can use native applications (represented by purple boxes) for simple mockups if necessary. Legacy users will enter the process during the first sharing of the task and the collaborative space on cloud at the authority of the administrator.

The second phase (Fig. 4) starts with the mockup and parallel involvement of cloud and legacy users in creation of product definition and creation/addition of legacy CAD parts/assembly in the cloud to create a first UPS (Unified Product Structure). This is the beginning of unified digital model to achieve an end to end digital thread. This stage starts with identification of an already existing engineering items in the cloud which can either be modified or reused. At the time when CBD users are creating or reusing the part, legacy users can do the same thing in a parallel session and add their part to the cloud. Activities like product definition, unified 3D model have been moved to web based applications to reduce the activities which were more time consuming on native

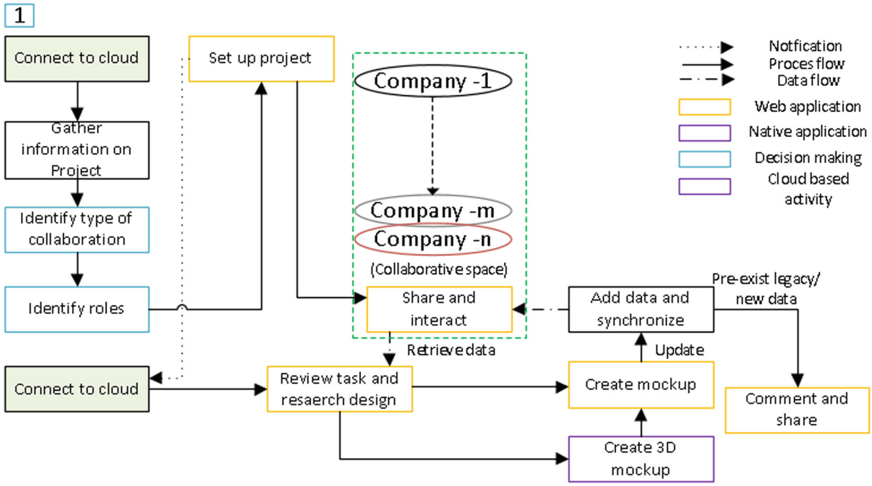

Fig. 3. Phase 1: initiation and conceptualization

applications. This is the stage where first review of the structure and drawing happens. As all thing stored in the cloud, with the help of web-based application, only part in contention of modification will be opened in the native applications thus reducing the load on the native application. Engineering connection between the CBD and legacy CAD parts remains intact during the process after the creation of UPS.

The third phase (Fig. 5) starts either with the entry of other legacy products/CAD product into the cloud or direct usage of UPS created in the second stage. This is the phase when again both legacy and cloud users can see the structure in the platform but holds authorization to change the part only in the software in which the part was created to reduce the complexity. Any modifications or creation of part, assembly and drawings can be carried out as per the comments coming from the previous stage. Once the assembly is finalized for the core view or an individual review, further roles can be added to carry out analyses like structural simulation etc. on the UPS.

The analyses files are saved back in the cloud so to allow for a review in web-based applications. Again, the main aim of this process is to simplify the reviewing task by allowing to be carried out in the web-based applications (3D and 2D annotations review) other than on the installed applications which requires more time and cost. Items here can have their maturity change if required. All the "in working" parts that are cleared in the review can be released. This stage ends with the submission of UPS with all the analyses files shared in the cloud and accessible easily through the web applications.

The fourth stage (Fig. 6) starts with the assessment of the reviewer's comments to check the product architecture again before releasing the assembly. All tasks are later closed and the project manager who initiated the task can send an approval for the product to be sent for further usage like marketing or manufacturing.

At any stage a separate change action management or release management action plan can be initiated.

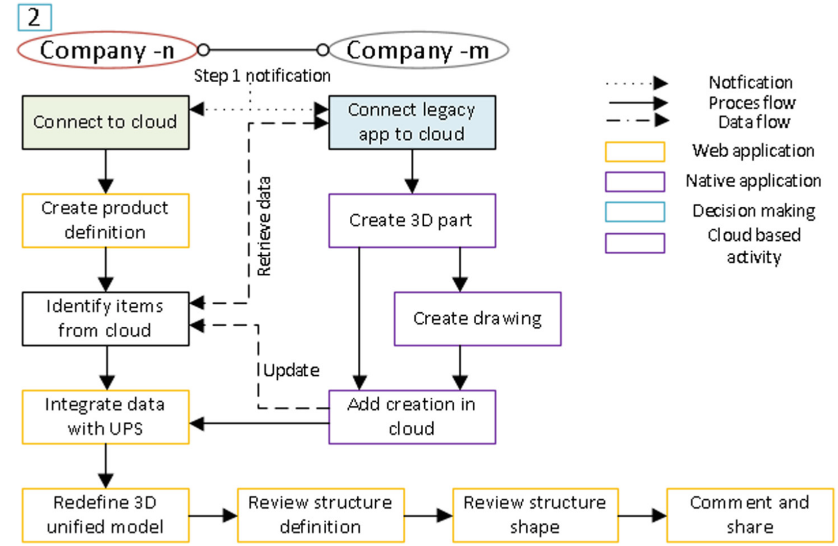

Fig. 4. Phase 2: preliminary design and review

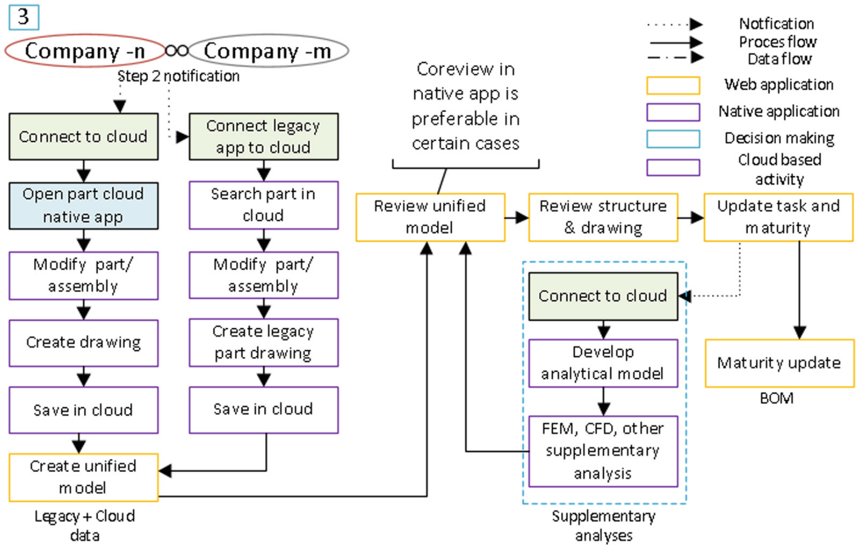

Fig. 5. Phase 3: mature design and analysis

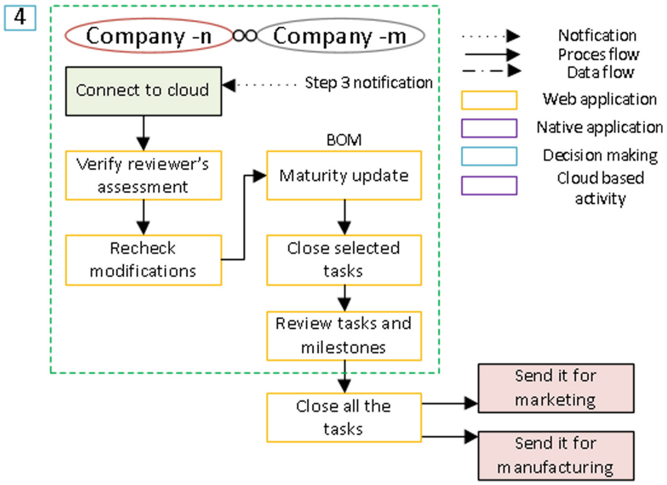

Fig. 6. Phase 4: final design

3.3 CBCD Case Study

As to understand the value of CBCD system proposed in form of its methodology, a case study (Fig. 7) was formulated where one type of users used legacy systems and others used cloud based system. For Cloud based system, Dassault Systemes's 3D experience platform was chose as a test bed and for legacy system, CATIA V5 was chosen as a test bed. Two software can be replaced by others if there is network/connection exist between legacy and CBD system. In the given scenario, an interaction between OEM and supplier has been studied and its feasibility was test based on the user experience during the design process and advantages have been identified.

In the current case study, a OEM is chosen which has access to cloud platform and all its services. Department concerned in the case study is a design department. There is a supplier which is responsible for providing certain CAD designs to be used by OEM as per request to form a new assembly of wheel as a unified digital model (aim of CBCD) comprising of both legacy data and CBD data. Supplier is equipped with a legacy system like CATIA V5 and can be given access to cloud only by the OEM as per the project requirement.

The acquisition of data was carried out by using "3DSearch", "3DSwym" web applications whereas the legacy user was able to access the same thing via "CATIA V5" when it was connected to the cloud. Communication was carried out by "3DMessaging" apps which was done via mobile phone. During co review, PMO (OEM project manager) and DEO (OEM design engineer) carried out in real time co-review in "3DEXPERIENCE CATIA" in the stage 3 and rest of the co review was carried out in web-based application "3DReview" accessible from mobile devices. The product architect was designed and visualized in the web application "Product Structure Editor". All stakeholders were added in the "3DSpace" connected to the cloud. Exploration of the existing component and comparing it with the existing engineering

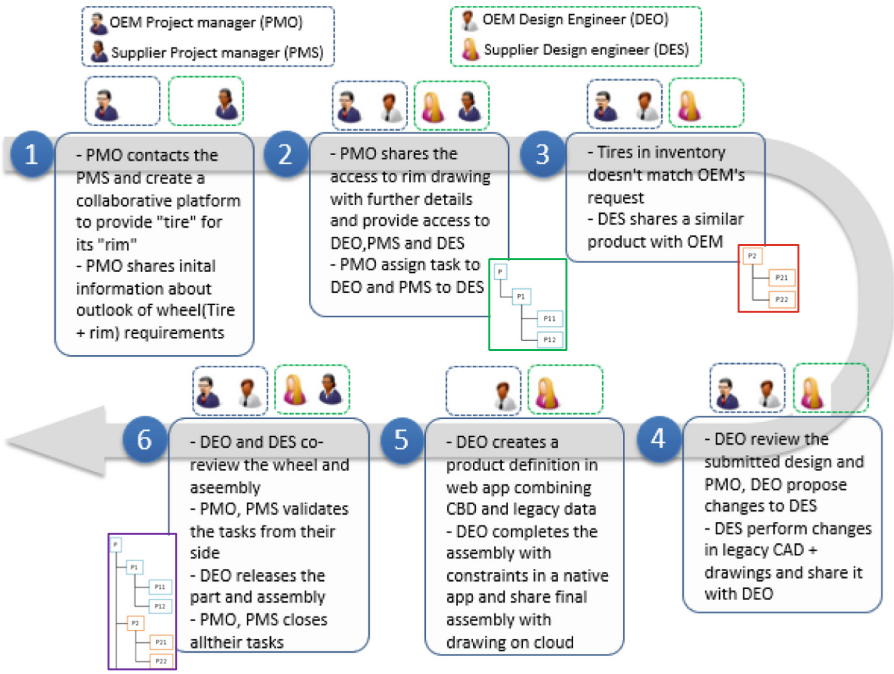

Fig. 7. Cross company collaboration process flow

item was carried out using “Product Explorer” and “Compare “web applications. Once the part was uploaded in the cloud, a new UPS was created in the web application Product Structure editor and near actual assembly was created in 3D Compose web for which later engineering connections were created in the CBD native application.

4 Results

When CBCD methodology was carried out, following observations were made:

- Single unified digital model comprising of multi CAD structure was found to bring fluidity in the design process
- File based legacy CAD data became engineering items in the CBCD which can be accessed, used and indexed again thus extending their life
- Tenancy offers legacy users to experience the advantages of the cloud platform without migrating their data
- Visualization of CBD data in CATIA VS is still not available in legacy system
- Transfer of certain functionalities were found to be interoperable like publications, materials and catalogues
- Product architecture, changing maturity, 3D and 2D review, collaborative tasks, cloud search, engineering items comparison, metrics reader, community, mail, product exploration, route tasks, cloud news via web applications really speed up

the design process because of non-requirements of doing things in native applications and their accessibility on mobile devices
- Locking mechanism with multi users was found to be robust as it took less than a minute for update across all the CBD and legacy systems.

5 Conclusion and Future Work

Our research started with the identification of issues related to Cloud Based Design and how it has not been explored fully. Our research presented a generic CBCD methodology involving all kind of design activities in cross company collaboration fashion via cloud by representing a complex scenario of big and small industries where collaboration happens between CBD system users and legacy users. Successful execution of case study showed us the merits associated with CBCD system like moving more activities on web based applications, challenges like issues with visualization and authoring of hybrid models and the importance of creating a truly hybrid digital data collaboration by involving different types of CAD data such that all collaborators can use just one data model even though the parts are authorized in their respective CAD origins. The future works involves testing the CBCD methodology with the other famous CAD systems available in market with the existing cloud test platform in order to understand the collaboration scenario, challenges of hybrid model usage, advantages of unified digital model to achieve start to end digital thread based on UPS.

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