A system framework for OKP product planning in a cloud-based design environment

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Abstract

Nowadays, one-of-a-kind (OKP) companies, which generally operate in an 'engineer-to-order' business mode, strive to deliver individualized products with quality to achieve customer satisfaction. Thus, an accurate and prompt analysis of customer requirements (CRs) in the early design stage is critical to its success. However, most OKP companies are small or medium-sized enterprises (SMEs) . Due to the limited resources and low product planning budget, they often cannot obtain abundant CR information nor can they afford the expense of complicated planning process. To address these issues, a system framework is proposed in support of OKP product planning process in a cloud-based design (CBD) environment. The challenges and future market niches of OKP companies are presented. The comparison of typical distributed systems shows that CBD, which utilizes advanced information technologies and business model, has advantages in providing sufficient resources, decreasing product development time span for OKP companies in a cost-efficient way. This article describes the proposed system architecture, the business interaction process and the information communication among customers, designers and marketing analysts at the product planning stage. To validate the proposed framework, a prototype system module *MyProduct* is under development in the CBD environment with an illustrative example.

Keywords: One-of-a-kind production; product planning; cloud-based design; cloud manufacturing; mass customisation

1. Introduction

Manufacturing industry has evolved through several phases since two centuries ago. It started with 'Craft Production', which 'design for customer' at a high cost and low efficiency. This is followed by 'Mass Production', i.e. 'design of customer' by offering a limited variety of products at a high efficiency [1]. More recently, 'Mass Customisation', i.e. 'design with customer' [2] and 'Mass

Personalization', i.e. 'design by customer' [3] emerged with an aim to satisfy customers on an individual basis at an affordable cost in mass efficiency. This tendency helps make 'market-of-one' a reality [4, 5]. Clearly, the emphasis of manufacturing has transferred from maximum production to maximum customisation, from standardised production process to flexible process, and from product-oriented to service-oriented [6]. One-of-a-kind production (OKP) is an extreme and special case within the scope of Mass Customisation [7], which has a focus on the 'market-of-one' and generally takes on the 'engineer-to-order' business model. It strives to deliver customized products based on each individual customer requirements (CRs) while maintaining the efficiency and quality of 'Mass Production' [8, 9].

It is generally acknowledged that nearly 80% of the manufacturing cost of a product is determined by its design process [10]. Personalized products, services, and communications attract customers' attention, and foster customer retention and loyalty by addressing customers' latent needs [11]. Thus, acquiring and analysing CRs effectively during the product planning stage plays a significant role for the survival of OKP companies. OKP companies are mostly small or medium-sized enterprises (SMEs) with limited resources. Due to design uncertainties and corresponding re-designs, their cost is normally higher than those of product-focused manufacturing companies [12]. Lack of efficient information communication in the existing web-based environment also leads to severe impediment to the success of an OKP company.

Cloud-based design (CBD), which is within the scope of the newly emerged cloud manufacturing (CMfg) paradigm, was first articulated by Wu et al. [13]. CBD can flourish OKP companies mainly in two aspects: 1) the 'pay-per-use' business model which they only need to pay a periodic utilization or subscription fee. It significantly reduces the expense on IT and manufacturing infrastructure [14, 15]; 2) in a cloud-based environment, OKP companies can get access to abundant design resources through multiple channels, e.g. online community, Software-as-a-service (SaaS) and etc.

This paper proposes a cloud-based system framework that enables OKP companies to identify and analyse CRs in a cost-efficient way at the product planning stage. The rest of the paper is organised as follows. Section 2 provides a brief overview of CMfg research and recent development of product planning research. Section 3 depicted the characteristics, challenges and future market niches of OKP companies. A comparison of typical distributed systems is also given to show the advantages of CBD and the tendency of OKP companies to be integrated in its environment. The conceptual CBD framework is proposed with its roles, definitions and examples given in Section 4, and accompanied by an introduction of the proposed system architecture. Section 5 discusses the business interaction process in the proposed framework at the product planning stage. Also, the interaction communications between customers, designers and marketing analysts are described. A prototype system module *MyProduct* is proposed accordingly, and its data model, major functions and user interface are described by an example of bicycle project planning in Section 6. Section 7 concludes the paper and highlights the future work.

2. Literature review

Cloud technology has been widely utilized in many manufacturing areas, such as resource planning, collaborative computer-aided design, manufacturing system monitoring and etc. [6]. However, there is not much effort directed towards the early design stage, in particular the product planning process. This section provides a review of the recent development of product planning process, the cloud-based design concepts and the existing CMfg system architectures.

2.1 Recent development of product planning process

Product planning refers to the process of eliciting and mapping CRs into engineering characteristics (ECs), which is at the very beginning stage of the product development process. In literature, several methods were proposed to model explicit and implicit CRs, such as product configurator, Kansei Engineering, quality function deployment (QFD), Kano model and etc.

Product configurator stands for a knowledge-based method to match CRs with the prospective product attributes one by one to derive the final product. In general, there are three types of product configurator, i.e.: rule-based, case-based and model based ones [16]. Though it shows great performance in retrieving defined attributes [17, 18], however, it relies strongly on the specific design knowledge from customers (e.g. parameters, features), which cannot be utilized for novel customers, nor to elicit subjective needs, such as appearance, aesthetics, and etc. [19].

Kansei Engineering, also known as affective design, was first proposed by Nagamachi (1995) [20], which is defined as *'translating technology of a consumer's feeling of the product to the design elements'*. Studies show that real time collection of affective data can derive optimized customer pleasure [21]. Furthermore, understanding of individual customer's affective requirements is a prerequisite of predicting successful product design to achieve customer satisfaction [22]. However, Kansei engineering still relies on customers' explicit expression of their feelings by language, which might not be a reliable medium for interpreting design concerns [5]

QFD, first proposed by Akao [23], provides a systematic method to analyse CRs and to transfer them into ECs all over the product development [15, 24] stages by the so-called 'House of Quality' (HoQ). It has been validated as capable of improving customer satisfaction, reducing product development cost, decreasing time span, and enhancing collaboration in the product development process [25]. Since CR information processing is critical, in literature, the major concerns of QFD are to determine the final importance rating of CRs at the product planning stage [26, 27]. Both relative importance rating and competitive market analysis are considered to obtain the final priorities of CRs. Also, due to the imprecise or vague expression by customers, fuzzy set and rough set based methods have been utilized to handle the subjective information, such as fuzzy AHP [28, 29], fuzzy ANP [30, 31] and rough number method [32]. On the other hand, Kano model [33] which describes customer preferences by classes of attractive quality, one dimensional quality, must be quality and indifferent quality, has been utilized to integrate with the QFD method to enhance the understanding of CRs, leading to superior product planning process [34-36].

However, as implementing the above techniques is a complex task and requires professionals to operate, they are usually performed by large enterprises with sufficient resources and qualified professionals [37]. OKP companies only have limited sufficient resources and expertise, which are unable to implement them. Therefore, they need to be more innovative in quest for an effective way of overcoming those shortages, e.g. taking into account the abundant cloud resources in a collaborative design environment.

2.2 Cloud manufacturing

2.2.1 Definition of CMfg and CBD

Cloud Manufacturing (CMfg), as a newly emerged manufacturing paradigm, was first proposed as '*a computing and service-oriented manufacturing model developed from existing advanced manufacturing models and information technologies*' [38]. It aims to maximise the sharing and utilization of various manufacturing resources and capabilities for on-demand use, and also provide safe, low cost, good quality manufacturing services all along the manufacturing lifecycle [39]. There are quite a few definitions of CMfg in literature [40-43], all of which share some similar meanings and promote a paradigm of servitization of manufacturing resources and capability, on-demand usage, and 'pay-per-use' business model.

Furthermore, Wu et al. [42] derived a concept of CBDM (Cloud-Based Design and Manufacturing): CBD and cloud-based manufacturing (CBM) from the existing CMfg definitions. For the first time, design stage, i.e. CBD, is typically emphasized in the CMfg environment. 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 a distributed and collaborative environment' [44]. According to [14], a CBD system normally includes some basic requirements, such as cloud computing-based, ubiquitously accessible by mobile devices, and capable of managing complex information flows.

2.2.2 *Existing system architecture*

Layered architectures and system frameworks for CMfg had been presented by many researchers, such as 3-layer architecture [45], 4-layer architecture [6, 41, 46], 5-layer architecture [38, 43], 7-layer architecture [39] and 12-layer architecture [47]. Each varied in its complexity and level of demonstrated potential. Yet, they all share a similar layered structure comprising *resources layer, service layer* and *application layer*. Also, most of the proposed systems are of a generic nature with a main focus on manufacturing activities; however, there is no guideline for companies to integrate these architectures and frameworks into the early design stage.

3. Tendency towards cloud-based product planning

There are three main characteristics in the OKP product planning stage: *high customisation, high product variety in mass efficiency,* and *limited resources* [12, 48, 49]. To deal with these challenges, Koren et al. [50] proposed a novel concept of ‘open product’ and pointed out a novel way of incorporating limited resources, small market share and innovative ideas of OKP companies into corporation with large companies.

In the CBD environment, OKP companies may flourish through more channels, such as cooperation with original equipment manufacturers (OEMs), individual customers and other OKP companies. Based on the literature review [14, 41, 44, 51], Table 1 is compiled to compare different distributed manufacturing systems, i.e. web-based, agent-based, and cloud-based systems at the product planning stage. CBD has shown its unique advantages in dealing with the existing challenges of OKP companies, which are summarised as follows.

- *Decreased time span of product development*

(1) *Agility:* the ability to allocate the amount of software and hardware resources dynamically.

(2) *Scalability:* the ability to allow companies to quickly respond to the changing requirement by scaling up or down.

(3) *High performance computing:* the ability to provide intelligent search for design solutions enabled by semantic web technology and social network analysis [42, 51]

- *Effective information communication and abundant resources*

(1) *Crowdsourcing* enhances the product design innovation process with abundant resources by acquiring novel ideas from the general public.

(2) *Networked environment* enables designers, customers and marketing analysts in geographical different locations to communicate effectively.

(3) *Social media* provide channels, i.e. Facebook and Twitters, for customers, marketing analysts and engineers to obtain effective information regarding the product development.

(4) *Resource pooling* offers the way to serve service demanders in a ‘pay-per-use’ model with the design resources of cloud service provider pooled.

(5) *Search engine* provides an effective way for both customers and designers to narrow down the scope of requests, and achieve information efficiently.

- *High customization in security*

(1) *A ubiquitous network access* enables customers’ and engineers’ privacy in the product planning process.

(2) *Multi-tenancy* enables multiple tenants’ usage with just a single instance of application [14], which benefit customers’ participation in the co-design process.

Furthermore, by adopting cloud-based approach, OKP companies have little need to invest much money in hiring engineer experts or purchasing manufacturing equipment. Instead, they are more flexible in managing their own businesses by having instant access to business and technical solutions in a ‘pay-per-use’ way in the cloud [6].

Based on the above advantages, this research work proposes a system framework in the following sections to integrate OKP company product planning process in a CBD environment.

Table 1 Comparison of typical distributed manufacturing systems at product planning stage

Characteristics	Type			Advantages		
	Web-based	Agent-based	Cloud-based	Decreased time span of product development	Effective information communication and abundant resources	High customisation in security
Salability	√	√	√	√		
Agility	√	√	√	√		
High performance computing		√	√	√		
Networked environment		√	√	√	√	
Social media			√	√	√	
Resource pooling			√	√	√	
Search engine			√	√	√	
Crowdsourcing			√	√	√	
Multi-tenancy			√	√		√
Ubiquitous access			√			√

4. Proposed system framework for CBD

A typical CMfg system consists of four roles, i.e. service demander (or service consumer), service provider, infrastructure provider and platform provider. The system normally has a layered structure consisting of, for example, *a resource layer*, *a service layer* and *an application layer*. In this research, a conceptual framework of CBD with its system architecture is proposed for the purpose of managing product planning services in a cloud environment.

4.1 A conceptual framework of the CBD environment

Figure 1 shows the proposed conceptual framework in the CBD environment. The cloud service infrastructure provider (e.g. Amazon EC2 [52], Dropbox [53] and VMware [54]) hosts virtualized computing resources over the Internet, which offers data storage, high speed computing and other functions, acting as the base of the cloud environment. The cloud service platform provider (e.g. Salesforce [55], Google big query [56] and Windows Azure [57]) allows service provider and service demander to manage, develop and run Web applications by providing the platform, which is the core role in CBD. OKP companies, as the cloud service provider, utilize the resources in the cloud and provide product design services to customers through the cloud service platform, are the main participants in the CBD design activities. Customers, as the cloud service demander, consume services offered by the cloud. They are the end users in the cloud environment which has the largest range of scope, as shown in Fig. 1. Table 2 gives the definitions and examples of each fundamental role in the CBD environment.

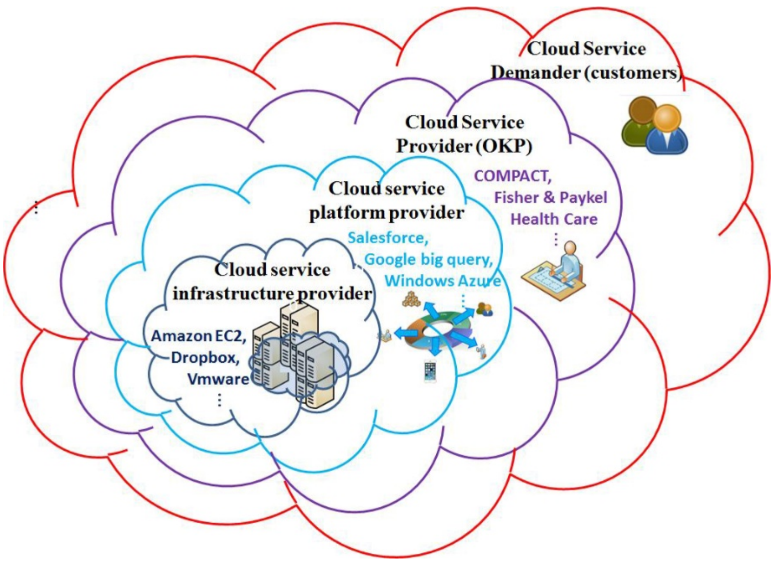

Fig. 1 OKP companies in cloud based design environment

Table 2 Roles, definitions and examples in the proposed conceptual framework [15]

Role	Definition	Example
Cloud service infrastructure provider	A third-party provider hosts virtualized computing resources over the Internet	Dropbox, Amazon EC2, VMware
Cloud service platform provider	A third-party provides a platform allowing service provider and demander to develop, run and manage Web applications without building and maintaining the infrastructure	Salesforce, Google big query, Windows Azure
Cloud service provider	An entity that provides services in the cloud service platform	OKP companies, e.g.: COMPACT, Fisher & Paykel Health Care
Cloud service demander	An entity that consumes services offered by the cloud service provider	Individual customers or companies

4.2 System architecture of CBD at the product planning stage

There are three layers in the proposed system architecture supporting OKP product planning process in the CBD environment, i.e.: *resource layer*, *service layer* and *application layer* (Fig. 2).

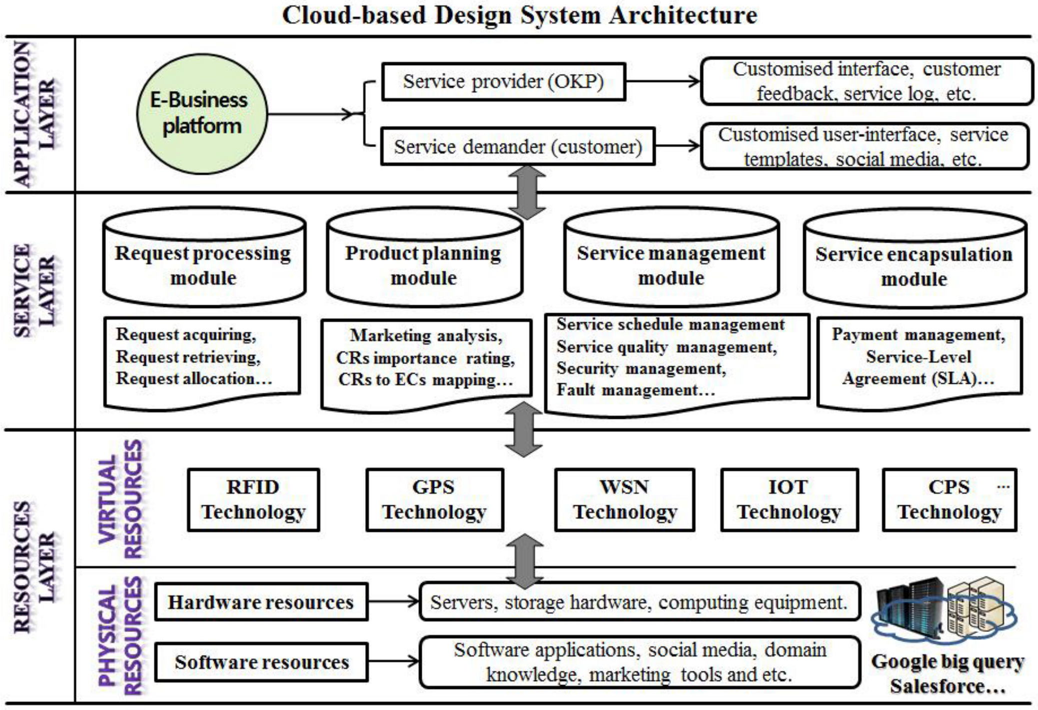

Fig. 2 CBD system architecture at the product planning stage

4.2.1 Resources layer

The *resource layer* is a pool of product planning resources; it contains two sub-layers, the *physical resource sub-layer* and the *virtual resource sub-layer.* The *physical resource sub-layer* consists of both hardware resources and software resources. Software resources include software applications, domain knowledge, social media, marketing analyse tools and etc., whereas hardware resources refer to servers, storage hardware and computing equipment. The *virtual resource sub-layer* is a virtual pool of abstracted logical resources from their underlying physical resources. It contains three key functions: (1) identifying product planning resources, (2) virtualising them, and (3) monitoring their real time status. In order to identify product planning resources, quite a few technologies can be adopted [58], e.g., radio-frequency identification (RFID), wireless sensor network (WSN), internet of things (IOT), cyber physical system (CPS), global positioning system (GPS) and etc. The satisfaction of design service and efficiency of service encapsulation are determined by the quality of virtualisation. And the resource information and its real time status are delivered to the *service layer* by on-demand request [6].

4.2.2 Service layer

The *service layer* is mainly responsible for processing service requests and managing encapsulated services [6]. It consists of four modules, the *request processing module*, *product planning module*, *service encapsulation module* and *service management module.*

- *Request processing module*

The *request processing module* is responsible for assessing initial CRs through the process of request acquisition, request retrieval and request allocation. The request acquisition function in this layer is responsible for capturing initial CRs and refining them into useful product design related information. Request retrieval function is in charge of finding the potential service providers that can fulfil these CRs based on historical information stored in the knowledge base. It helps enhance design resource allocation by re-using the historical knowledge, and thus improves the system efficiency and guarantee the service quality. Request allocation function mainly focused on allocating the prospective OKP companies intelligently to the customers after comparing the customer requests with service providers' design capabilities.

- *Product planning module*

The *product planning module* plays the key role in transferring CRs into ECs for further design process. It consists of three functions: (1) market analysis of CRs; (2) determining customer's final importance ratings of CRs; and (3) mapping CRs into ECs. Market analysis of CRs refers to the process of acquiring and analysing CRs through marketing strategies, such as conjoint analysis, online questionnaire, focus group and web-based co-design toolkits. In the CBD environment, CRs can be obtained through many ways, such as historical review or purchase, crowdsourcing and social media. These channels enable OKP companies to gather CR information effectively. Determining customer's final importance ratings of CRs is a crucial step in achieving the product development success. It mainly contains two parts: relative importance rating and competitive market analysis, which can be offered by the platform provider as a SaaS for OKP companies to utilize. Mapping CRs into ECs refers to the process that based on the priority rankings of CRs, designers interpret them into design terms, such as functional requirements or non-functional requirements [59] to get the basic design concepts of the product. In this system, OKP companies will not be hand-tied by the limited resources in conducting the complicated QFD or Kano modelling process. These tools have already been provided by the cloud service platform providers based on service composition, which deals with the ability to extract useful services from available resources and to combine them when needed for value-added operations [60].

- *Service management module*

The *service management module* ensures data security, enables service quality, and detects service faults [6]. Data security is supported by compressing and encrypting sensitive data, e.g.: customer information, design resource, and intellectual properties (IP) at the storage level, and enabled by the network middleware technologies. Service quality, which is enabled by prompt response to customers, intelligent allocation of design resources, and accurate analysis of CRs. Product planning with good quality of service can better satisfy CRs and therefore, achieve more competiveness in the market. Service fault should be detected and recovered with minimum down time. A backup solution subjects to the current resource availability status should be activated in the meantime of service restoration.

- *Service encapsulation module*

The *service encapsulation module* is mainly responsible for generating a Service-Level Agreement (SLA) according to the selected service scheme [6]. Liability is defined clearly in the agreement, thus ensuring a much easier recovery from any service failure. Besides, this module also offers the billing mechanism. OKP companies and customers, as the end users in CBD environment, their consumption billings resemble the measurement of consumption and the allocation of product planning costs.

4.2.3 Application layer

The *application layer* serves as an interface between the end users and the CBD system. This layer provides an E-business platform for both service providers and service demanders to communicate and operate. For customers, they can utilize a package of service templates to request customised services. For OKP companies, the *application layer* offers a customised interface for CR information management, such as service log, feedback of customers and etc.

5. Product planning process in the CBD environment

In CBD environment, service demanders request product development services from the cloud, while service providers offer these services by either outsourcing them or obtaining sufficient resources in the cloud. On one side, an OKP company can act as the service provider which sells services to users, and on the other side, it can be a customer which buys services from other service providers. Due to the lack of guidance in its integration in the cloud-based environment, this section discusses the business interaction process of the product planning process in CBD, and its information communication among different roles.

5.1 Business interaction process

Figure 3 shows the business interaction process of the proposed product planning process in a CBD environment. OKP companies, as the service providers, are integrated into the cloud-based platform with customised graphical user interfaces (GUIs) [15], just as an App listed in the App Store.

5.1.1 Pre-process

The pre-process stands for the procedures of selecting a proper service provider:

Step 1: Cloud service demander requests a cloud service in the CBD environment.

Step 2: Cloud service infrastructure provider offers the search engine for demanders to select the proper cloud service platform providers.

Step 3: Cloud service infrastructure provider retrieves historical information based on inputs.

Step 4: Cloud service demander choose from the feasible cloud service platform providers.

Step 5: Platform providers acquire demander’s initial requirements and make a real-time quote

Step 6: Platform providers classify the demander’s tasks intelligently to match with suitable service providers.

Step 7: Demander select the prospective service providers from list.

Step 8: After demander's selection, platform provider will allocate the related resources to the selected service provider [6], as illustrated in Section 4.2.2.

For the pre-process steps, if the demanders are certain with the exact platform provider, they can skip *Step 2* and *3*.

5.1.2 Identify CRs

Step 9: Demanders provide CRs to the service provider.

Step 10: Service provider identifies CRs in the cloud.

In order to obtain the 'Voice of Customer', in the CBD environment, many existing marketing strategies can be utilized, such as purchase history, online focus group, lead user analysis, ethnography, brainstorm and etc. [61]. Also, social media information and the virtual-reality techniques could be exploited to facilitate customers' co-design participation for identifying the CRs.

5.1.3 Undertake competitive marketing analysis

This part stands for the procedures of analysing the identified CRs in the CBD environment:

Step 11: Analyse CRs. Both the relative importance ratings and competitive market analysis of CRs should be considered by the service providers. The prior one generally can be obtained through direct rating or pairwise comparison from customers, while the latter one can be achieved by benchmarking of its competitors from customers' perceptions. Then, the improvement ratios of each CR will be evaluated by the engineers in both a qualitative and quantitative way, respectively [62].

Step 12: Customers participate in the co-creation process. In CBD environment, the customers can communicate or design with both marketing team and design team efficiently with GUIs and co-design toolkits [15].

Step 13: Platform provider offers essential marketing information through multi-channels, such as social media, purchase history, comments and reviews.

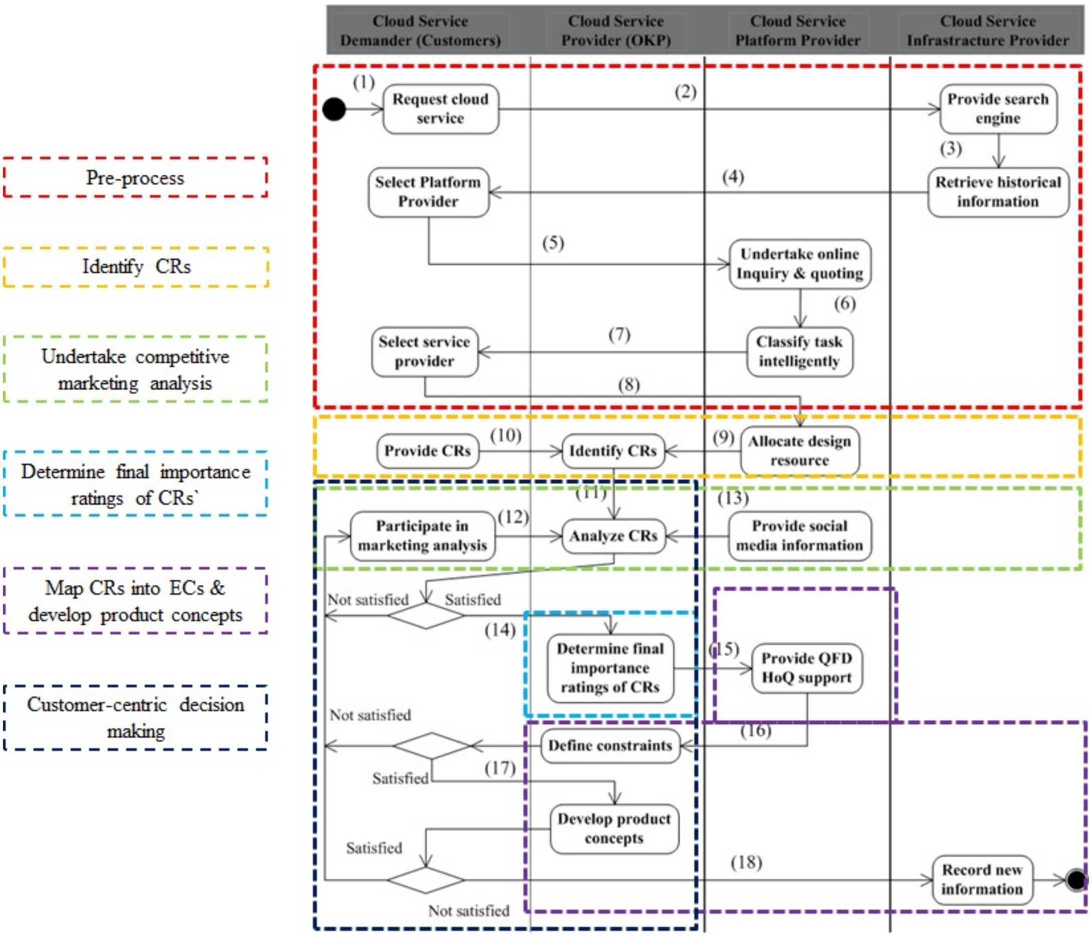

Fig. 3 Product planning interaction process in CBD

5.1.4 Determine the final importance ratings of CRs

Step 14: Service provider determines the final importance ratings of CRs based on the previous steps. Conjoint analysis [63] has been widely adopted for the assessment. Also, in order to handle the imprecise and vague information from customers' subjective expressions, many methods had been utilized, such as fuzzy AHP [29] method and rough number based method [32]. They can be implemented in the CBD environment as a SaaS for OKP companies to buy per-use [15].

5.1.5 Map CRs into ECs

Step 15: Platform provider searches for experts or SaaS options (e.g. product planning HoQ) for OKP companies to transfer final rankings of CRs into the priority ratings of ECs. OKP companies may utilize SaaS tools or inquire the experts with specific knowledge in the cloud [15].

Step 16: Designers of service provider define the constraints based on the ECs.

Step 17: Designers of service provider develop product concepts to satisfy demanders.

Step 18: The acceptable concepts are stored in the database as the design history information.

5.1.6 Customer-centric decision making

With the dynamic change of CRs and customers' subjective evaluation, the interaction process at the product planning stage is often iterative. Customers participate to make their own decisions on the following steps:

Step 10: Satisfied with the derived CRs?

Step 12: Satisfied with the relative importance ratings of CRs?

Step 14: Satisfied with the final importance ratings of CRs?

Step 16: Satisfied with the ECs?

Step 17: Satisfied with the product concept?

Online negotiation is utilized to achieve the satisfaction of the customers [64]. Otherwise, the product planning process needs to be re-undertaken from *Step 11*.

The above introduced interaction process has a number of advantages. The CBD environment improves the real-time communication between demanders and service providers in a collaborative way. The design resources can be effectively achieved and utilized in the cloud, which enhances the business performance of OKP companies. The 'pay-per-use' business model enables OKP companies to have access to abundant CRs information in a cost-efficient way.

5.2 Information communication

Improving the communications among customers, designers and marketing analysts in the design process is one of the ultimate goals in engineering design research [14]. Other than the conventional product planning process that customers negotiate with marketing analysts and then transfer the information to designers in a sequential way, in the CBD environment, all the communications are conducted through cloud service platform interface in a parallel way, as shown in Fig. 4.

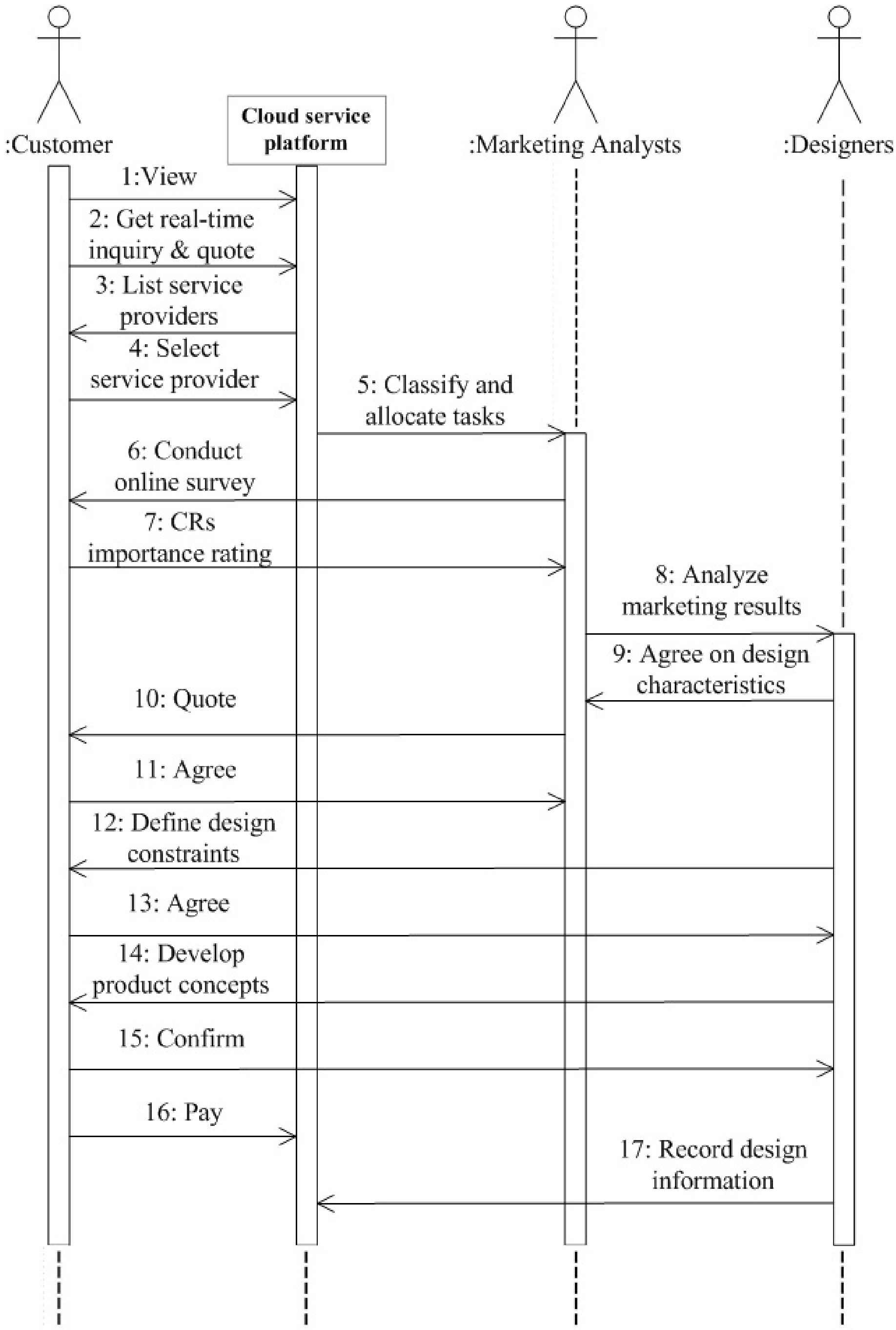

Fig. 4 Information communication at the product planning stage in CBD

Customers can search and view through the cloud platform interface (*Step 1*), provide CRs online through social media, crowdsourcing or other approaches (*Step 2*), select possible product service providers (*Step 4*), and give their perceptions towards the CRs (*Step 7*). Also, customers can make decisions or even co-design with the designers and marketing analysts (*Steps 11*, *13 and 15*) to fulfil their satisfaction, and finally pay the bills (*Step 16*). Designers make agreements with the marketing analysts (*Step 9*), discuss design information with customers through online chat and video, or even undertake co-creation process based on the collaborative design software (*Step 12 and 14*), and finally record design information into the knowledge base (*Step 17*). Marketing analysts can negotiate with customers by online quoting or surveys (*Step 6 and 10*), and also conduct competitive marketing analysis and deliver the results to designers (*Step 8*).

In CBD platform, communication tools, such as instant messaging, virtual meeting and screen sharing are integrated to enable multi-channel information exchange [14]. All of these bring benefits to the OKP companies in a collaborative environment. Both marketing analysts and designers can achieve and analyse customer information efficiently. Besides, it encourages customers' participation, and provides a way for co-design process, which benefits OKP companies of interpreting CRs accurately.

6. Prototype system implementation

In order to validate the proposed framework, *MyProduct* system module, acting as the cloud service platform provider at product planning stage, is under development based on our previous prototype system infrastructure of *MCloud* [6]. Its data model and prospective user interface have been developed, so as to give an overall picture of the cloud-based product planning process with an example of bicycle project planning. Due to its complexity, much work still remains to be done, such as intelligent algorithms and methods for resource allocation, historical information retrieval, and final importance rating.

6.1 System infrastructure

The *MCloud* system, with its unified ontology modelling and cloud management mechanism, was applied in managing hybrid manufacturing clouds among companies. The system was tested in among a group of companies worldwide, showing its flexibility in allowing them to create different cloud models for their periodic business goals [6]. The system infrastructure of *MCloud* is shown in Fig. 5. It utilizes a SQL server to store all business related data. An application server is set up for hosting all the web services, such as resource encapsulation, request processing, and etc. Additionally, it utilizes a web server, i.e. Amazon Web Service (AWS) [52] to host the main website that receives HTTP requests from cloud users. Also, advanced web development technologies, such as elastic cloud computing, responsive web design, and web service, are adopted for its case study test. As the system spans across multiple tiers, it requires dealing with APIs in different programming languages, such as C# and Java. The prototype system encapsulates stand-alone functions as web services and utilizes REST (Representational State Transfer) [65] to ensure smooth communications between different web services.

Currently, the *MyProduct* module, as a sub module of *MCloud* system, has been deployed in a Windows 7 localhost environment. The main system is being developed by using ASP.NET MVC [66] framework in Visual Studio 2013, and hosted by Internet Information Services (IIS). The database is established in MySQL Enterprise Edition. Owing to the flexibility of Amazon EC2, the proposed system module can be easily implemented into the public networked environment in a 'pay-per-use' model.

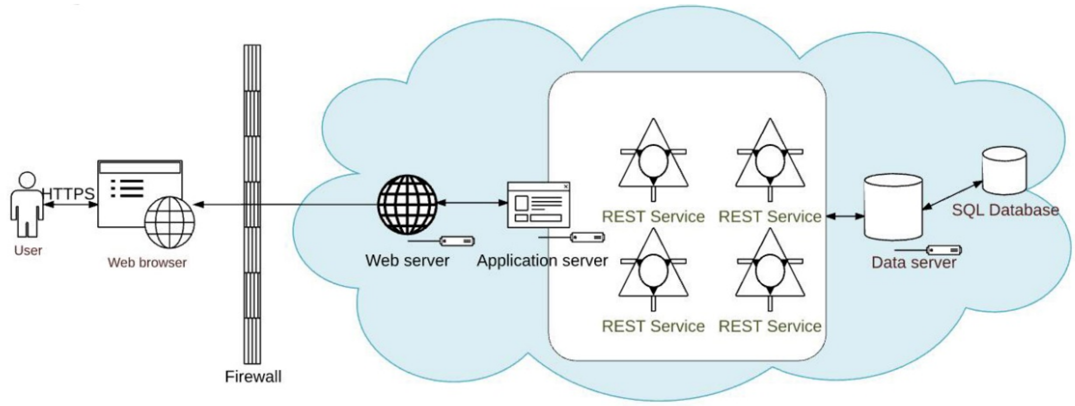

Fig. 5 *MCloud* system infrastructure

6.2 UML data model of *MyProduct* module

MyProduct module concentrates on the interaction processes among customers, designers and marketing analysts in the product planning process. To achieve this, the system module should get data related to both requests of customers and their analysis by designers and marketing analysts. The data model of the interaction process is exemplified in Fig. 6 using Unified Model Language (UML) [67]. It contains three main classes, i.e. *Service Class, Customer Class, OKP Companies Class.*

(1) *Service Class.* It refers to the representation of all the base concepts around service from both customers and service providers. It covers service description, payment method, service quality evaluation and etc. A service is requested by a customer through GUIs and transmitted as a *Service Description File* in XML format (Figure 7) for internet communications. It specifies the service type, quality of service (QoS) expectation, cost, and service specifications. A service may contain several *Service Units*. Each *Service Unit* is mapped to a specific resource offered by a service provider. The *Payment Method Class* is associated with a service individual.

(2) *Customer Class.* It refers to the service request expectations and post-service evaluations from customers. *Customer Class* acquires customer information and captures CRs by *Customer Requirement Class*, and intelligently allocates the CRs to the *OKP companies Class* through the *Service Class*. Also, *Customer Review Class* records the review and suggestions towards the design concepts.

(3) *OKP Companies Class.* It refers to the service providers offering product planning services to the customers. *OKP Companies Class* captures the information of each on-going service by recoding

marketing analysts (*Marketing Analyst Class*), conducting competitive marketing analysis (*Marketing Analysis Class* and *Relative Importance Rating Class*), and designers (*Designer Class*) undertaking conceptual design process (*Mapping CR to EC Class*) respectively. It works collaboratively with the *Service Class* and *Customer Class* to maintain the accuracy and efficiency.

This data model supports most of the information linked to the users (e.g. customers, OKP companies) in the product planning process. It specifies the service description, customer information and service provider information, thus providing an efficient mechanism to improve service quality and user experience.

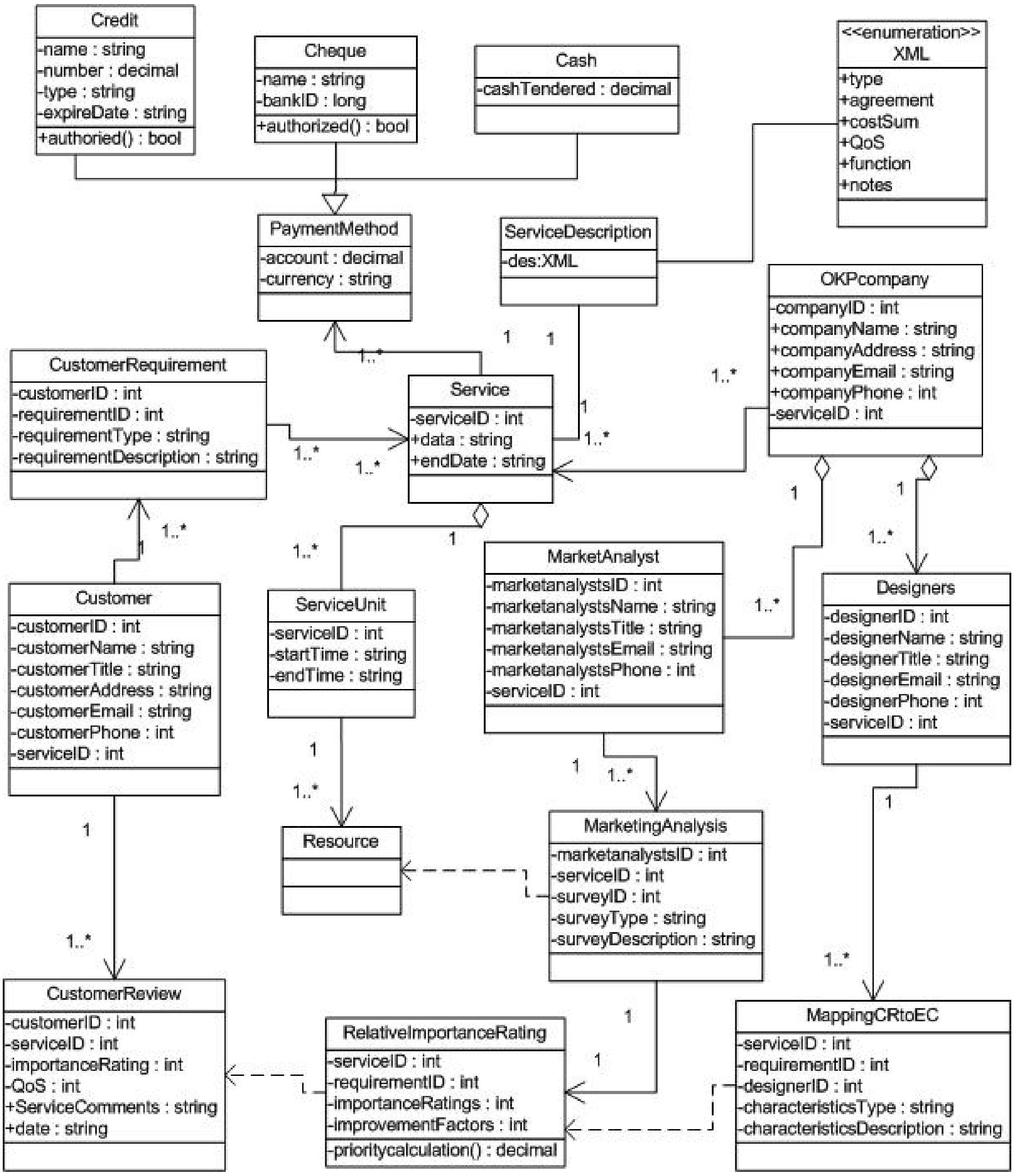

Fig. 6 UML data model of *MyProduct* module

```xml
<?xml version="1.0" encoding="UTF-8"?>
<cloud_service_customer_requests>
  <product category="bicycle">
    <way_of_use>Leisure travel, on road use</way_of_use>
    <rust_prevention_method>Not sure, maybe protection painting?</rust_prevention_method>
    <frame_set_shape category="bicycle">
        <shape>Triangle</shape>
    </frame_set_shape>
    <vibration_damper>Double dampers</vibration_damper>
    <type_of_material category="bicycle">
        <material>Carbon-fiber</material>
    </type_of_material>
    <contact_method category="contact">
        <contact>Email</contact>
    </contact_method>
    <design_method category="design">
        <design>Co-design</design>
    </design_method>
    <other_preferences>Please give me the due date. Can I design my own logo?</other_preferences>
  </product>
</cloud_service_customer_requests>
```

Fig. 7 XML representation of customer request

6.3 An illustrative example

In order to give an overall view of the proposed system module, its six key functions are depicted in a sequential way, as shown in Fig. 8 and a case study of a personalized bicycle project planning is illustrated in this section

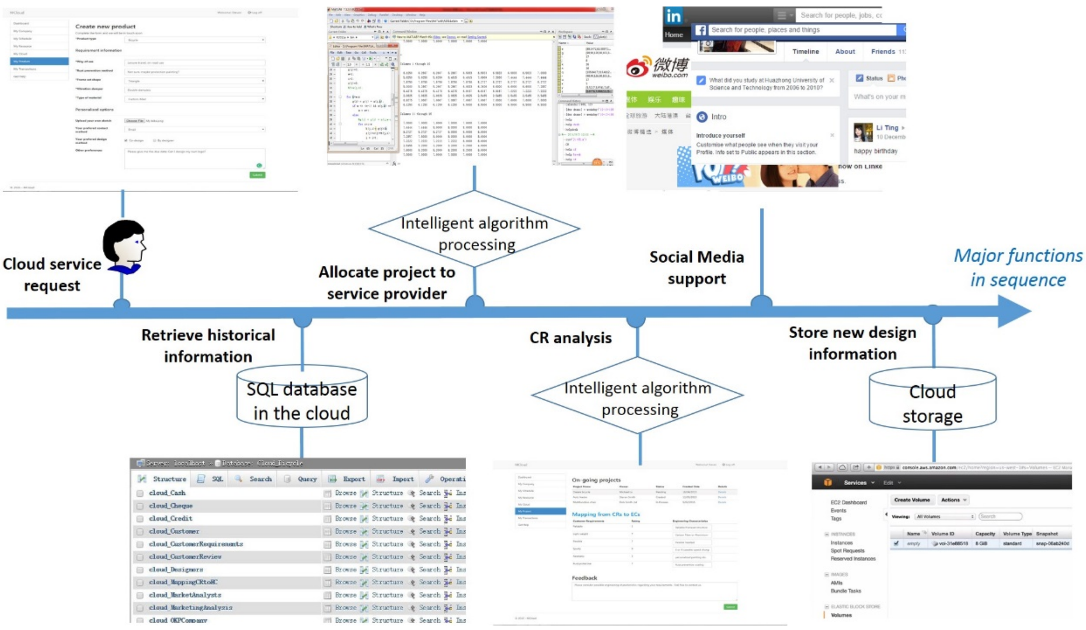

Fig. 8 Major functions in *MyProduct* module

Function 1: Customer requests cloud service. A demander can log into the *MyProduct* module and complete the inquiry form for raising new requests of a product. Fig. 9 shows one prospective service demander's GUIs in the CBD environment. The platform provides mandatory information of the desired bicycle, including way of use, rust prevention method, type of material, frameset shape and so on. The criterion of this information is pre-determined by a group of potential service providers consistently. Besides, additional information, such as customer's own sketch and other personalised options can also be provided through the interface, which will be transmitted into an XML file (Fig. 7) for Internet communications once submitted.

Function 2: Retrieve historical information. Once the form is submitted, the system needs to store all the customer information with a specific customer ID in the SQL database, and also retrieves historical design information among prospective cloud service providers. For example, if a customer requests a bicycle with ‘mountain road usage’, ‘triangular frameset shape’, ‘carbon fibre material’ and ‘double dampers’, the system could match the information with OKP company A and OKP company B, which have previously designed such products.

Function 3: Allocate project to service providers. With the retrieved information, the system module needs to select the appropriate service providers for customers to choose from. The matching process can be done by either rule-based reasoning, or case-based reasoning methods with intelligent algorithms, such as neural network and genetic algorithm. Also, we have proposed an ontology-based method in previous studies [6], which can be utilized to deal with such semantic information.

Function 4: CR analysis. This is the most critical function in the proposed system module, which determines the success of product development. It contains different information, such as relative importance ratings, final importance assessments, competitive market analysis, EC information and so on. A prospective designer’s interface of mapping CRs into ECs in the CBD environment is shown in Fig. 10. The GUI displays the essential information, including status of projects, CR information, customer preference ratings and its corresponding ECs. Also, designers may give feedback to the customers directly regarding their requests by online submission. In such a case, the customers and the OKP companies are integrated in a collaborative environment. The company may either conduct this process with its own experts, or outsource it to other service providers in the cloud.

Function 5: Social media support. As we mentioned in Section 5.1, nowadays, social media information plays a significant role in CR elicitation, decision of purchase, user experience acquiring. Thus, in order to support the CR analysis, the proposed system module added links to several popular social media channels, such as Facebook, Twitter and Weibo, which provide embedded links for applications on the website. Thus, service providers can establish their own accounts through multi-channels and link them with the module.

Function 6: Storing new design information. With the status of an on-going project showing ‘completed’, all the design information (e.g. CRs, reviews, feedback, types of ratings, ECs and other related documents) needs to be recorded in the cloud database for customer’s preference modelling, OKP companies’ design re-use and platform’s cloud service allocation, respectively. Advanced web technologies, such as cloud computing, AWS EC2 and web services, should be utilized to manage those information.

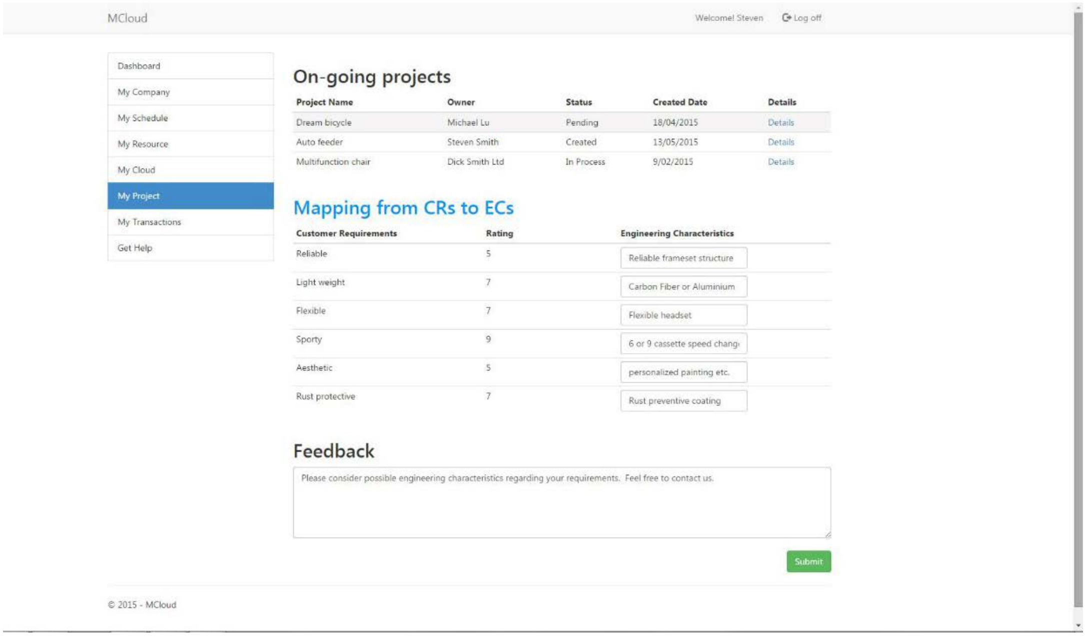

Fig. 9 Service demander's interface in *MyProduct* module

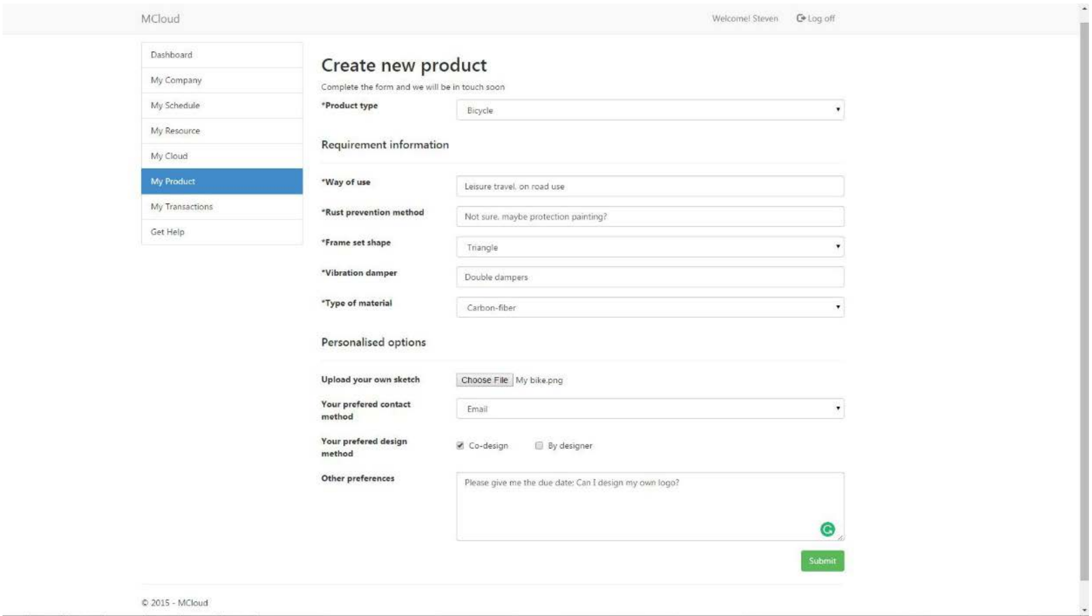

Fig. 10 Service provider's interface in *MyProduct* module

7. Conclusions and future work

OKP companies are mostly SMEs. They generally operate in an 'engineer-to-order' business model. Their market niches mainly rely on the highly-customized products with mass efficiency. To achieve this, capturing and analysing 'voice of customer' rapidly and accurately from the very beginning of product design stage plays a significant role. However, due to their limited resources and low budget, current web-based OKP companies may neither identify and analysis CRs accurately and effectively, nor afford the complicated product planning process expense. It is a necessity for them to overcome these shortages by adopting innovative methods in an effective way.

In this paper, a comparison of typical distributed systems is given, showing that CBD has its advantages in high performance computing, social media support, resource pooling and etc., which would enhance the product planning process of OKP companies. It can effectively overcome the challenges, such as rapidly changing CRs with uncertainty; decreased time span of product design in high product variety; ineffective information communication with limited resources. However, there is little work in literature concerning the early design stage in a cloud-based environment.

Aiming to integrate the product planning process of OKP companies into the CBD environment, this paper proposed a conceptual framework with a three-layered system architecture. OKP companies, as the cloud service providers, offer services in the cloud service platform by sharing their design resources to the customers and also obtaining abundant resources from other service providers in the cloud. Different from the existing system architecture, the *request service module* and *product planning module,* as the key modules in the service layer, focused on the early design information derived from CRs, and correspondingly transferred them into ECs. It utilizes the resources from social media or systematic tool, such as QFD and Kano models in a ‘pay-per-use’ model in the cloud, which avoids the large amount of up-front cost, and enhances the information processing.

The business interaction processes in among service demanders, service providers, platform providers and infrastructure providers show the systematic mechanism of product planning process, which gives guidance to current OKP companies in a cloud-based environment. And the non-sequential interactive information communications between customers, designers and marketing analysts provide an efficient collaborative way of product development process other than the traditional sequential design process.

To validate the proposed framework, a prototype system module *MyProduct* is proposed based on the infrastructure of *MCloud* system in a cloud-based environment. The UML data model, key functions and user interfaces are described with an example of bicycle project planning to show how customers and OKP companies can be integrated into the CBD environment to realize the product planning process towards mass customization and personalization.

The implementation of the proposed system module is a very complicated process. Generally, it requires large companies (e.g. OEMs) or the government to provide the cloud-based platform with standard interface so that OKP companies or SMEs can join in as the vendors. Due to the concerns of investment expense, profit sharing, IP protection, intelligent resource allocation, and the limitations within the current existing OKP companies, it may not be practical for commercial use at current stage. The main future work lies in: 1. Develop intelligent algorithms to optimize resource allocation process and customer preference decision making process at product planning stage; 2. Implement the system module and test it in companies; 3. Extend the proposed system module with further design process, such as embodiment design and detail design process in the CBD environment; and 4. Propose a cloud-based cost estimation method with business intelligence plans.

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