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Research on the Design of Beekeeping Pollination Service System Under the Perspective of Symbiosis Theory

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Abstract. In the realm of rural revitalization driven by technological advancements, the concept of "smart agriculture" assumes a paramount role. Within this context, apiculture and crop cultivation exhibit a profound interdependence, yet, historically, these two domains have developed somewhat independently in terms of digital resource cultivation and the establishment of information platforms. This disjointedness has resulted in a lack of efficient interaction and organic integration. In this article, we delve into the symbiotic dynamics between apiculture and crop cultivation, guided by the principles of symbiosis theory. We propose a symbiotic model rooted in design thinking and harnessing the potential of information technology to optimize mutual benefits among beekeepers, agriculturalists, bee species, and the ecological environment. By crafting an innovative bee pollination service system, we strive to achieve a multifaceted equilibrium of demand, promote comprehensive interplay within the industry, and foster the sustainable development of ecosystems. Consequently, our study offers strategic insights that extend beyond the agricultural sector, serving as a scholarly reference for the construction of symbiotic service systems in diverse fields.

Keywords. Apiculture, Pollination, Service design, Symbiosis theory, Smart agriculture

1. Introduction

In light of the rural revitalization strategy's emphasis on sustainable agricultural development, particular attention has been directed towards apiculture, referred to as the "wing of agriculture"[1]. Beyond the immediate economic gains derived from enhanced yields of bee products and crops, this engagement also engenders ancillary advantages, encompassing ecological preservation and the safeguarding of species diversity. Furthermore, it plays a pivotal role in promoting environmentally friendly agricultural practices and ecosystem stability, which is crucial for the sustainability of modern agriculture and ecological conservation[2]. In contemporary beekeeping, developed nations acknowledge honey bee pollination as a fundamental element, establishing comprehensive industry chains and institutions tailored to individual national contexts.

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Conversely, in China, the bee pollination industry remains marginalized within the agricultural production landscape. While recent government and research focus has shifted towards encouraging the industrialization of bee pollination, the absence of a mature pollination service chain hinders the realization of full benefits for each participant in the system.

Currently, there exists a notable dearth of systematic design and in-depth research on the beekeeping pollination service system. Despite existing studies on apiculture and bee pollination, few have concentrated on establishing a holistic and robust beekeeping pollination service system, particularly in refining the service chain and optimizing the synergistic operations of each participant. The construction of a comprehensive and effective beekeeping pollination service system stands as a pressing objective, requiring urgent resolution. A meticulous exploration of the beekeeping pollination service system is imperative to address this research gap. This study adopts a symbiosis theory perspective in investigating the beekeeping pollination service system. The aim is to construct a holistic and robust service chain, optimize the synergistic operations of each participant, elevate the user experience, and propel the healthy development of the system. This approach is envisioned to enhance the efficiency of agricultural production, uphold ecological equilibrium, and foster rural economic development.

2. Theory

2.1. Key Tenets of Symbiosis Theory

The concept of "symbiosis" encapsulates the interconnectedness of elements and found its initial expression within the realm of biology, introduced by the German biologist Anton De Bary[3]. As interdisciplinary boundaries have strengthened and theoretical research has matured, symbiosis theory's fundamental ideas and research paradigms have gradually permeated the humanities. Within symbiosis theory, the basic unit is the symbiotic unit, the symbiotic mode serves as the constitutive matrix and the symbiotic environment represents the external factor[4]. These elements merge to form a cooperative and mutually reciprocal symbiotic system, interconnected through a symbiosis matrix, to achieve efficient, mutually beneficial outcomes and construct a symbiotic value framework.

Symbiosis theory advocates for a perspective that frames issues through the lens of connectivity, enabling a comprehensive and developmental understanding of relationships among and between entities. Drawing upon the concepts and analytical tools of symbiosis theory, the analysis of the beekeeping pollination service system and its related beekeeping equipment products can illuminate the interrelationships among symbiotic entities, facilitating the construction of a mutually advantageous symbiotic model and an expansion of system benefits.

2.2. Application of Symbiosis Theory in Service System Design

Symbiosis theory asserts that entities within an ecosystem achieve coexistence and mutual prosperity through interdependence and mutual benefit, transcending competitive interactions. Applied to service system design, this theory enhances our understanding of the interplay between user needs and the system, allowing for more precise design

across various service facets. The result is an enriched user experience and the creation of business value.

In service system design influenced by symbiosis theory, the focus is on the interdependent and mutually beneficial relationship between service providers and recipients. This perspective deepens our comprehension of stakeholder dynamics within a service system, emphasizing collaborative evolution and sustainable development. Conversely, non-symbiotic service design tends to concentrate on unilateral service provision and demand fulfillment, often neglecting reciprocal influences and relationships between service providers and recipients, thereby hindering the creation of enduring system value.

The infusion of symbiosis theory encourages us to view stakeholders in service system design as integral components of a broader ecosystem, encompassing not only service providers and users but also the environment, other organizations, and society. This holistic perspective contributes to a comprehensive grasp of each stakeholder's needs, expectations, and impacts. Compared to traditional service system design, symbiosis theory underscores the interdependence among various ecosystem constituents and the pursuit of common interests. It implies closer collaboration and coordination among stakeholders in a service system to enhance its effectiveness and sustainability[5]. In contrast to conventional service design, symbiosis theory accentuates the dynamic nature of systems, incorporating considerations of interactions and changes among system constituents[6]. This necessitates the inclusion of elements such as competition, adaptation, and strategic planning in service system design to ensure its resilience and adaptability in an ever-changing environment. Moreover, symbiosis theory extends its purview to encompass concerns about sustainability and eco-friendliness within the service system design. It necessitates the integration of environmental and social impact considerations to mitigate adverse effects and promote the system's long-term sustainability.

In summation, symbiosis theory furnishes a comprehensive framework for service system design. It emphasizes interdependence, collaboration, sustainability, user engagement, and system evolution. Practically, adopting the symbiosis theory empowers designers to delve deeper into the intricacies of service systems, enhancing their adaptability and efficiency. This approach accommodates the diverse and personalized needs of distinct stakeholders and augments the efficacy and adaptability of service systems. Ultimately cultivates a more sustainable and dynamic service ecosystem. By emphasizing the interconnections and cooperation between a system's internal and external components, symbiosis theory enhances the comprehensiveness and practicality of service design[7].

3. Design Insights in Beekeeping Pollination Service Systems

Within the traditional beekeeping pollination model, communication between beekeepers and growers typically relies on telephone or face-to-face interactions, which suffer from inefficiencies, delays, miscommunications, and a lack of transparency in information exchange. Furthermore, growers often require specific bee colonies for different crops. Unfortunately, due to limited contact channels and a shortage of trading partners, beekeepers may struggle to fulfill these requirements, resulting in suboptimal pollination outcomes. Lack of communication and information asymmetry between beekeepers and growers may lead to opacity and distrust in bee pollination services.

The beekeeping pollination service system encompasses an "ecosystem" involving products, individuals, the environment, and society. Harmonizing the interests of multiple stakeholders and guiding the system toward a sustainable development model is essential. Challenges associated with sustainable development in the transition to a sustainable society encompass technical aspects and the outcomes of social, cultural, political, and economic interactions[8].

As an encompassing theoretical framework, symbiosis theory offers the capacity to analyze the intricate system of multi-role stakeholders, including users, enterprises, and social organizations, from a broader perspective. It facilitates the effective integration of resources and the enhancement of benefits, leading to improved organizational structures, altered production methods, resolution of societal issues, and, ultimately, the attainment of comprehensive sustainable development across the realms of the environment, economy, society, and culture[9]. In the sustainable society development trend context, this innovative approach addresses ecological protection, economic model adjustment, and social equity concerns. It comprehensively caters to the needs of all stakeholders and engenders a novel, healthy, and stable system structure and internal-external environment[10].

In summary, this study endeavors to transform the current state of the disorganized beekeeping pollination system. It introduces symbiosis theory to construct a symbiotic service system for beekeeping pollination. The study explores the symbiotic logic underlying each facet of the service system and designs a comprehensive and seamless beekeeping pollination service system.

4. Theoretical Application

The core focus of the beekeeping pollination service system centers on the cultivation of mutually beneficial relationships and collective advancement among all relevant stakeholders, including users, the environment, and society[11]. By drawing upon the guiding principles of symbiosis theory, the aim is to foster the development of multi-party symbiotic associations. To realize the enhancement of comprehensive benefits is the guiding direction for constructing a symbiotic development system and represents the practical objective of the beekeeping pollination service.

Presently, the predominant emphasis in intelligent beekeeping resides in informatization and visualization management aspects, such as internal data collection within beehives, intelligent apiary management, and apiary safety warnings. Most smart beekeeping products are predominantly anchored in these dimensions. However, in this study, we adopt the symbiosis theory framework to delve into the intricate issues of beekeeping pollination, especially within the context of mobile beekeeping models characterized by challenges like inadequate information transfer and mobility constraints of beehives. In light of this theory, we propose a mutually advantageous symbiotic approach to maximize overall benefits for multiple stakeholders, encompassing beekeepers, growers, bee populations, and the broader ecosystem.

4.1. Analysis of Symbiotic Patterns in Beekeeping Pollination

Within the framework of symbiosis theory, the symbiotic unit, symbiotic model, and symbiotic environment represent the foundational elements.

In the beekeeping pollination service symbiosis system, the symbiotic units primarily consist of a pollination service supply unit and a pollination service consumption unit. The former includes beekeepers, beekeeping bases, and other internal symbiotic constituents, whereas the latter incorporates individual agricultural growers, farm planting bases, and similar internal symbiotic entities. The absence of specialized official bee pollination service organizations in China has resulted in limited and suboptimal communication between these two symbiotic units. Furthermore, the absence of standardization and third-party oversight has eroded the effectiveness of the service significantly. Hence, breaking down these barriers between symbiotic units and establishing a connecting conduit to foster cooperation and symbiosis between both parties is paramount to realizing a mutually beneficial bee pollination service system.

Symbiotic modes encompass various relationships, including parasitism, deviant symbiosis, and reciprocal symbiosis. In the context of the beekeeping pollination service system, the two symbiotic units engage in a mutually beneficial symbiotic relationship. A robust symbiotic relationship facilitates energy exchange and regeneration between these units, culminating in mutually advantageous symbiotic benefits.

Within this system, the macro-control and policy guidance provided by the state facilitate information and energy exchanges among the symbiotic units, thereby promoting the efficient operation of the service environment within the bee industry. This spans the economic resource environment, human resource environment, and the social and cultural environment within the system, culminating in establishing a stable and healthy beekeeping pollination system model. The symbiosis model of this service system is analyzed in Figure 1.

Figure 1. Analysis of Symbiotic Patterns.

4.2. Construction of the Beekeeping Pollination Symbiosis System

Informed by symbiosis theory, this paper proposes a comprehensive beekeeping pollination service system strategy. Central to this strategy is leveraging the Internet to connect and utilize systematic information resources. It involves creating a beekeeping pollination service platform with a novel paid pollination order system. This platform

enables beekeepers and growers to engage in bee rental services, facilitating data collection and analysis for service feedback and guidance. Additionally, it integrates resources from bee companies, brands, cooperatives, and research institutes to offer relevant services to beekeepers.

Drawing from symbiosis theory, new service resource modules are continually embedded based on emerging demands and subsequently updated to enhance the transhumance beekeeping experience for beekeepers. This approach aims to foster mutually beneficial relationships and sustainable development among all stakeholders[12], as illustrated in the service system framework depicted in Figure 2.

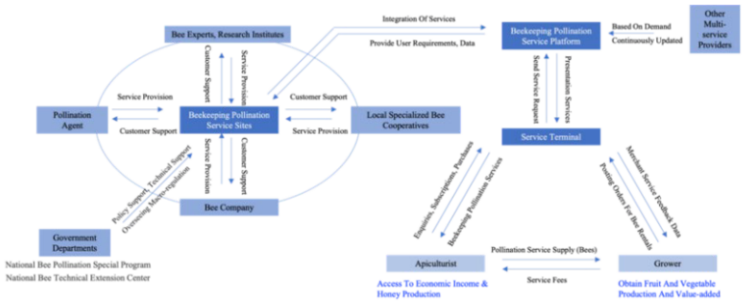

Figure 2. Service System Framework.

5. Design Practice

5.1. Service System Construction

The prevailing beekeeping development model faces challenges that necessitate revision. Beekeepers grapple with the need for reliable, real-time honey source information during the bee transfer process, intricate bee release planning, and the labor-intensive task of hive transportation, consuming substantial time and energy. Additionally, the lack of a comprehensive service chain when dealing with fruit farmers complicates aligning pollination service supply with customer demand, posing challenges to the rights and interests of both parties and hindering the transformation of China's beekeeping industry. In response, this paper proposes the construction of a bee transfer and release service system, leveraging the existing beekeeping pollination process.

This service system addresses current challenges by introducing features like honey source information updates, bee release route recommendations, order-based bee rentals, pollination services, bee transfers, drone hive management, remote hive monitoring, and expert guidance on data analysis. Seamlessly integrated into the beekeepers' transfer and release processes, these services ensure a high-quality user experience.

Furthermore, the incorporation of symbiosis theory and the integration of various social, industrial, and service resources enable convenient and rapid access to diverse resources and services, creating a cohesive and efficient system framework that is both expandable and sustainable.

Through this system, beekeepers can efficiently conduct beekeeping pollination, offer paid pollination services, and secure economic benefits beyond the sale of bee products. Growers, on the other hand, benefit economically from increased yields and improved fruit and vegetable quality. Beyond economic gains, the system contributes to ecological benefits by reducing the need for agricultural fertilizers, supporting the development of ecological and green agriculture, and playing a pivotal role in preserving agricultural biodiversity and stability.

The system's value proposition revolves around resource consolidation, a comprehensive service system strategy spanning the entire beekeeping pollination process, full utilization of the system's information resources, and the facilitation of an optimal beekeeping experience. It aims to balance the interests of ecology, industry, and various stakeholders. A stakeholder map is presented in Figure 3, and a service blueprint is illustrated in Figure 4 to visualize the service system.

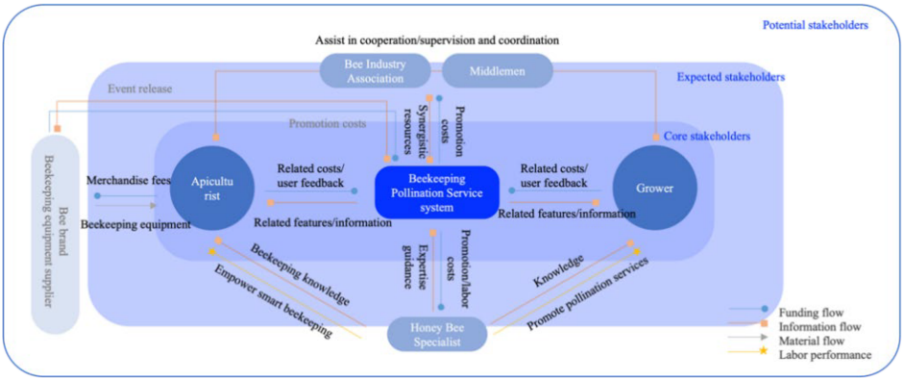

Figure 3. Stakeholder Map.

Figure 4. Service Blueprint.

Additionally, the paper proposes supportive beekeeping equipment products encompassing three core modules: an intelligent beehive module, a transit module, and an operation and maintenance management software module. The core product design is shown in Figure 5.

Figure 5. Core Product Design.

The equipment product category comprises two distinct modules: an intelligent beehive module and a transit module. Tailored to individual beekeepers, these modules facilitate the efficient initiation of beekeeping pollination activities. The drone transportation module expedites the relocation of beehives, minimizing labor and time costs, and enabling beekeepers to transfer bees quickly and effortlessly. The hive module, through data collection and analysis, facilitates remote monitoring of temperature, humidity, honey production, and other hive-related metrics. This information is relayed to beekeepers, ensuring bee safety and health, reducing beekeeper losses, simplifying hive maintenance for growers during pollination services, and featuring hive frames designed for automatic honey extraction. This design eliminates the need to open boxes, release bees, streamlines beekeeping tools, and reduces overall workload.

The software's core functionalities encompass instant honey source information, bee release route development, monitoring and management, rental bee pollination order management, intelligent early warning, and guidance services. The accompanying mobile application provides beekeepers with real-time hive status updates and visualized beekeeping data feedback. Additionally, the platform serves as a hub for beekeepers to access information, synchronize real-time messages from honey sources, plan bee-release routes, and inquire about honey bee pollination rental orders from fruit farmers along their routes. The service offers remote beekeeping guidance, intelligent early warning services, and online assistance through data synchronization. Enhancing the pollination service chain via the platform, safeguards the rights and interests of both transaction parties, fostering a mutually beneficial scenario for beekeepers and fruit growers. The detailed analysis of the product's functional architecture and the interaction process design of the operation and maintenance management software are illustrated in Figure 6.

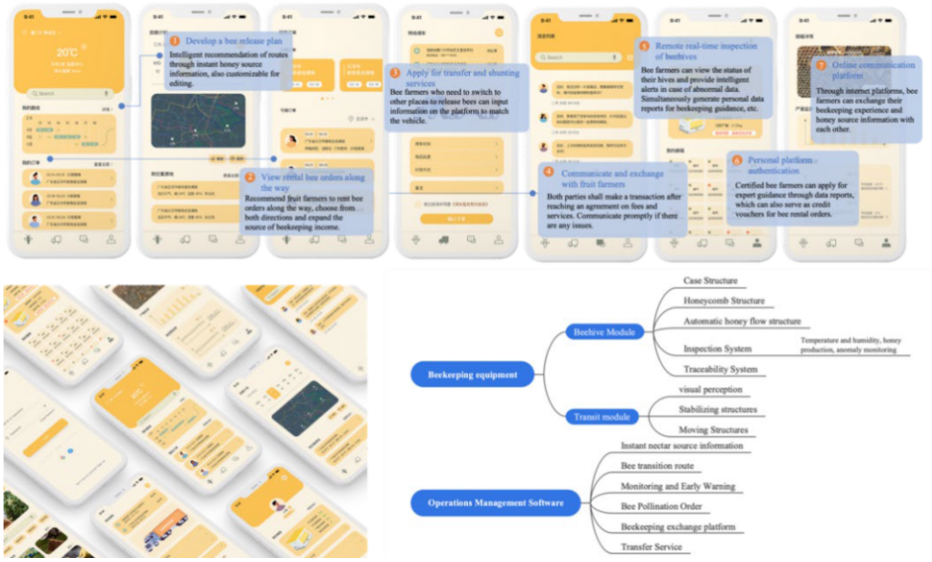

Figure 6. Functional Architecture and Interaction Process of Software.

5.2. Design Verification

To evaluate the design effectiveness and validate the impact of the beekeeping pollination service system, rooted in symbiosis theory, on beekeepers' user experience, an unstructured interview method was employed. Target users and domain experts were selectively engaged in the validation evaluation.

During the interviews, users acknowledged the notable optimization effect of the beekeeping pollination service system in terms of information integration and reinforcing the interconnection between beekeepers and fruit growers. This improvement significantly enhanced work efficiency and overall user experience. However, some users identified a perceived weakness in the system's safety warning functionality. Recommendations were made to incorporate multi-channel alarm methods, such as SMS and voice calls, for accessible and timely notifications. Given the reliance on a cloud platform, the importance of network security was underscored to prevent unauthorized access or data tampering. Establishing a user feedback channel for timely input collection was suggested for continuous improvement.

Expert insights emphasized the need for a more comprehensive economic benefit analysis of the service system, considering its profound impact on sustainability and development. This includes a cost-benefit ratio analysis covering construction, maintenance, and operational costs, alongside economic benefits. It also involves studying market potential, formulating a strategic promotion plan, and developing a return on investment prediction model. A deeper economic benefit analysis will contribute to a more accurate assessment of the system's feasibility, market positioning, and sustainability.

6. Conclusion

In this study, amidst a fragmented and underdeveloped beekeeping pollination service system, service design thinking, coupled with relevant tools and methods, is utilized to analyze the existing beekeeping pollination model. Additionally, symbiosis theory and associated thinking are employed to conceive and formulate the construction of a beekeeping pollination service system. These efforts aim to enhance the holistic user experience, generate business value, and facilitate the harmonious development of the various units within the system. The comprehensive and continuous beekeeping pollination service system presented in this paper casts its influence across the entirety of the beekeeping pollination process, ensuring that its diverse facets are seamlessly integrated and interconnected. Moreover, the incorporation of the symbiosis system permits this framework to consistently introduce and integrate new module resources. This approach fosters close-knit relationships among the constituent units and cultivates a healthy and mutually beneficial environment conducive to the sustainable development of beekeeping pollination services.

Nevertheless, beekeeping represents a vast and intricate industry system. The beekeeping equipment products and related service systems delineated in this paper may only address some of the complexities and contradictions inherent in the beekeeping industry and pollination model. Further refinement and testing are essential to validate and iterate upon these solutions. This iterative process will enable the offering to provide valuable insights for the integration and optimization of other service systems and meet the increasingly diverse needs of users. Future research could fruitfully explore this issue further by expanding towards experience, refinement, and sustainability of service design.

(1) System Intelligence and Enhancement: The enhancement of system intelligence is a key objective, involving a profound refinement of its design to adapt more adeptly to the intricate dynamics of beekeeping and agroecosystems. Utilizing symbiosis theory, the information transfer mechanism will be optimized, facilitating efficient monitoring and intelligent management of critical parameters like hive status and colony behavior. This optimization aims to elevate the system's adaptability and responsiveness to dynamic changes.

(2) Economic Benefits and Sustainability Consideration: A comprehensive exploration of the system's economic benefits and sustainability will be intensified, encompassing a thorough evaluation of its economic contributions and ecological impact throughout the beekeeping and agricultural industry chain. Applying symbiosis theory, the research will focus on resource optimization and environmental impact reduction to enhance the economic efficiency and sustainability of the system, fostering symbiotic and mutually prosperous relationships between beekeeping and agriculture.

(3) User Experience Research: Emphasis will be placed on refining the user experience by delving into the actual needs of beekeepers and growers. Grounded in symbiosis theory, this entails establishing a more intimate interaction between users and the system to bolster trust and satisfaction. User feedback will inform the optimization of the system's interface design and operational flow, aligning it more closely with users' habits and preferences, ultimately enhancing the overall user experience.

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