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A Systems Engineering Mechanism Applied to Knowledge-Intensive Service Industries

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ABSTRACT

A Knowledge-Intensive Service Industry Program was initiated by applying core technologies from systems engineering to new business models. This program uses a knowledge-management platform to integrate domain technologies, the work-flow process, collaborative design, cooperative service and business intelligence analysis, thereby introducing an innovative tool for phasing an outcome and entry/exit mechanism approach. Via this study, academic and research organizations with their accumulated technologies and intellectual properties in various industrial fields can collaborate with industrial alliance partners to develop knowledge-intensive service industries. Through the aid of new business models, systems engineering provides integrated solutions to all segments combining technology and marketing. This program applies systems engineering approaches to evaluate market needs, prospective business models and developmental processes for reducing the uncertainties associated with developing industries. A fresh-food logistics service system is used as an example to evaluate the effectiveness of the proposed mechanism and service. In the To-Be model, the system can provide accurate warehouse management information and conserve up to 50% of the floor area, 30% of the human resources and 30% to 50% of the energy efficiency.

***Key Words*:** service industries, knowledge-management platform, innovative mechanism, business models

系統工程於知識驅動之服務業創新機制的應用

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摘　要

系統工程之核心技術，可用於建立知識驅動之服務業計畫商業運轉模式。此服務業計畫係

使用知識管理平台去整合相關之技術、工作流程程序、產品協同設計、相互的服務及商業情報分析等，且已有成功的創新個案案例。藉由本研究，學術及研究機構可以以他們在各工業領域及協同之聯盟伙伴，所累積的技術及智慧財產權來發展知識驅動之服務業。系統工程之核心價值，在於可藉由新商業模式，提供有關技術或行銷方面之整體解決方案，因而本研究應用系統工程的方法來評估市場需求、未來的商業模式及發展程序，藉以降低由於未來產業發展之不確定性所帶來的風險。同時以生鮮食物後勤服務爲例來說明創新機制與系統服務之效益評估，研究結果顯示：系統因而可以提供精確的倉儲管理資訊，倉儲所需面積可節省達 50%，節省人力 30%，能源消耗減少 30%~50% 之間。

關鍵詞：服務業，知識管理平台，創新機制，商業模式

I. INTRODUCTION

Facing strong market competition, companies must meet business challenges with innovation as the new century is characterized by the fast pace of globalization. This trend is also influenced by the transition from an industrial to a service economy. The use of information and communication technologies (ICT) in the value-added process of a company plays an important role leading towards a knowledge-intensive service industry [1]. As in many well-developed countries in the world, Taiwan's service industry contributed 67.8% of the national GDP in 2003. This percentage may be less than in countries such as Australia [2]; however, it indicates that Taiwan is on-track in this new trend. To respond to this trend and to maintain the momentum of GDP growth for Taiwan economic development, the Ministry of Economic Affairs (MOEA) has impemented a new industry-development policy, through the Knowledge Intensive Service Industry Program (KISIP), to meet the needs of the existing service industry. This program will bring technology integration and service innovation to Taiwanese companies with the use of systems engineering and new business models. It is expected that this program will generate new opportunities for industries and eventually transform them into high-value, added-service enterprises.

Although the innovative use of information technology in business practices has revolutionized the way business is conducted in the global market, a mechanism for successful application of a new business model in the service industry has not yet been developed [2]. When logistic service as an example, improving the flexibility of the supply chain with respect to inventory location is important in customer service [4]. A new business model for improving flexibility in the supply chain must combine technology integration with service innovation. Furthermore, the mechanism for such combination will slucidate the creation of knowledge-intensive service industries. Therefore, the main purpose of this study is to focus on the application of an innovative mechanism in systems engineering to such industries; it also demonstrates the use of the mechanism in the fresh-food logistic service industry.

II. DEVELOPMENT STRATEGIES

Sucessful new service industies must have integration of systems, collaboration and globalization efforts [6] as their foundation for demonstrating a high added-value effect. In order to create new service industries, several strategies should be defined in the beginning stage of a knowledge-intensive program. As shown in fig. 1, knowledge-intensive service industries can have four different strategies, in accordance with different market and technology combinations. (1) In the current-technology and current-market segment, the strategy is focused on differentiation, which can be achieved by increasing customer bases, improving product/service usage, and searching for new applications for products/service. (2) In the new-technology and current-market segment, the strategy can be concentrated on new products/services, which can be realized through increasing functions, expanding lines, and developing new generationcs. One of the projects, the Fresh Food Logistic Service System project, in the Knowledge-Intensive Service Industry Program lies within this segment. (3) In the current-technology and new-market segment, the strategy is centered on market development, which can be obtained by expanding product/service coverage and entering a niche market. (4) In the new-technology and new-market segment, the strategy relies on multiple access to new product/service markets. However, new business models and systems engineering are indispensible elements for all of the segments. Systems engineering provides integrated system solutions to all of the technology and market combination segments through the help of new business models.

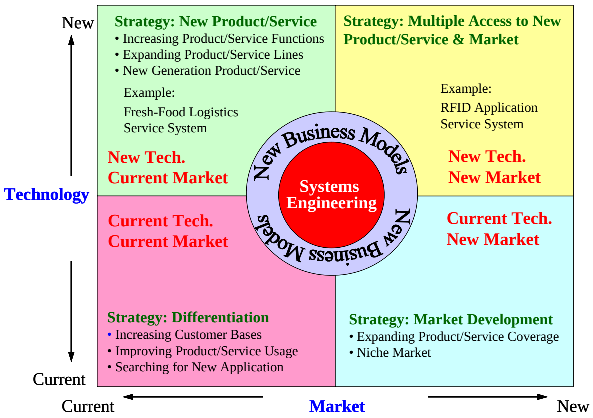

Fig. 1. Development strategies for Knowledge-Intensive Service Industries

III. SYSTEMATIC APPROACH FOR DEVELOPMENT

A knowledge-intensive service industry program is created with the use of a systems engineering process in order to meet the needs of customers. In the initial stage of a proposed program, the service needs from the customer generates system requirements through an innovative business-model analysis. Research organizations such as ITRI can integrate the necessary application technology to meet the system requirements and to constitute the developmental architecture of the proposed system. The trade-off for each proposed system will generate an interactive mechanism for the total solution and develop a prototype service system with a high market value. Research organizations can also perform verification and validation (V & V) for this prototype system to meet customers' needs. The government can initiate a policy and grant tax and loan incentives, standards, and certification issues for nuturing an industrial development environment. The government can also provide the needed resources to the cooperative partners in this program. The program will also need interdisciplinary system integration capabilities from research organizations and universities to provide the service industries with the necessary innovation technology tools and new business models. Institutions such as universities can provide simulation and testing of the underlying theoretical concepts of the proposed service system. A entirely new service industry sector can be established when a new service is spun-off from a research organization. The initialization of new service industries can generate other new service industries by further use of this process. These service industries can strengthen their competitive capability through industry alliances and a combination of different business service value chains with the assistance of this program during thesystem operation phase. Industries can eventually run the production, operation, maintenance and service of this newly constructed system. A cooperative relationship among industry, academia and research organizations is an interactive way wherein the knowledge resources among these organizations can be exchanged. Such cooperation is illustrated in fig. 2.

The development of a systematic approach and process for knowledge-intensive service industries, as shown in fig. 3, is adapted. The customers needs inject power to the wheel of an innovative business model and analysis. The formation of an industrial alliance from different parts of the value chain generates these needs and business models. An analysis of the needs and itstranslation into system requirements can provide power to the wheel of the system architecture with these requirements functioning as a linkage belt. Technological integration is the injection ingredient in this wheel. With system architecture and technological integration, a prototype system can be constructed with thegenerated system requirements. The empowered wheel can then provide system solutions to meet customer needs. The outcome of a prototype system gives the wheel a new approach. This systematic approach can generate either total solutions for the prototype system or transmit new system requirements to the wheel of the architecture. System solutions also function as linkage belts for both wheels. Such a combination of total solutions and a business model can then generate a spin-off company with the use of industrial promotion. As more customer needs drive the business model and analytical wheel, the resulting spin-offs from system solutions can then create new service industries.

IV. SELECTION CRITERIA

The main purpose of the Knowledge Intensive Service Industry Program is to promote systematic knowledge management with the use of integrated innovative concepts from science, engineering technology, business and

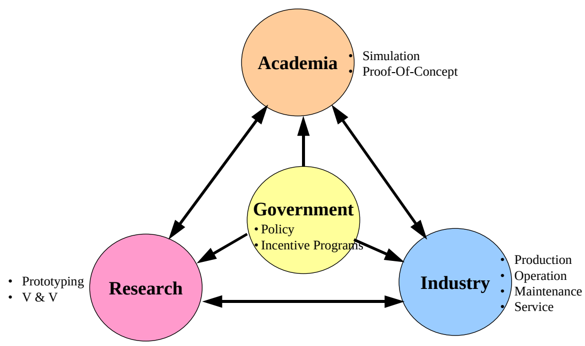

Fig. 2. Industry-Government-Academia-Research cooperative relationships

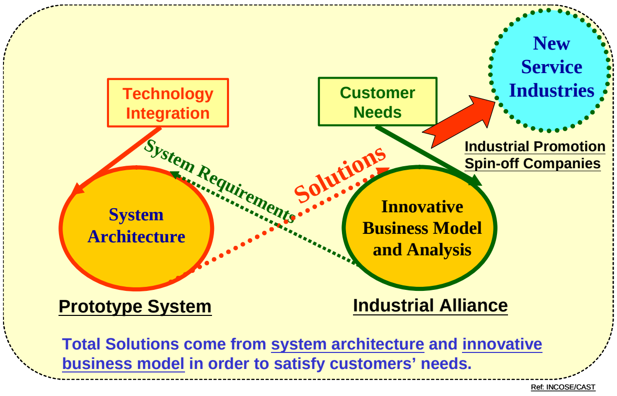

Fig. 3. Knowledge-intensive service industries systematic' approach and process

management which will elevate the added value for Taiwanese industries or create new service industries. The essential hierachical selection criteria for program can be summarized as high technological content, high added value, and high potential for future economic growth. A target service industry should have an international business scope, a high entrance level, and an innovative business model. Such an industry should also have an integrative capability for cross-domain technologies, a highly attractive incentive for industries to participate, and the ability to provide a systematic total solution. Finally, this industry should have the capability for cross-organizational resource integration, the ability to adopt technologies abstracted from the technology development programs of the MOEA, and further upgrade opportunities for the manufacturing sector. The successful formula for knowledge-intensive service industries can be expressed as:

Traditional Industry + New Domain Technology + New Business Model + ICT = HVA Service Industries

Here ICT indicates information and communication technology and HVA, high value added. This formula gives a qualitative instead of quantitative expression for knowledge-intensive service industries. Four project-wise evaluation criteria for selecting a strategic development project can be summarized as follows:

(1) The technological operation platform must have relatively high entry barriers and be capable of international and efficient operation.
(2) It must be service oriented and able to develop a new business model with formation scenarios from the new service industry.
(3) It should provide a systematic total solution with a capacity and mechanism for the market-oriented knowledge-intensive service business.
(4) Technological development for the projects should come from the core domain knowledge in the research organization and can be able to correspond more closely with business needs.

V. PROGRAM-PHASE OUTCOME AND ENTRY/EXIT MECHANISM

With the introduction of systems engineering methodology, the development of each service system project in the Knowledge-Intensive Service Industry Program will progress through four different phases, including proposal (phase 0), feasibility (phase 1), system development (phase 2), and operation and deployment (phase 3). During each transition between phases, three different gates have been established for system evaluation. Gate 1, Gate 2 and Gate 3 designate the decision points in the program. Phase 0 focuses on the service concept proposal. Phase 1 begins the feasibility study of the business and technological aspects of the preferred service system; Phase 2 begins the development of the knowledge-intensive service industry; Phase 3 shifts to system operation. In Gates 1, 2 and 3, a proposed service system runs through concept exploration, risk reduction, system development and demonstration, production and deployment, and finally to operation and support. Different reviews will be held to select a preferred system solution for each period. The work contents, phase outcomes, the phase role and position of research organizations such as ITRI, academia and industry are summarized in fig. 4. The entry/exit mechanism in the Program scope is also shown in this figure.

In each phase of the program, the program office will examine the preferred system solution by the criteria. In phase 0, the major contents such as the proposal and its business scenario, industrial needs and new opportunities, innovative business models, technical requirement analysis, system-operations architecture, and anticipated benefits will be examined. The system requirements, analysis report and innovation proposal can serve as the outcome. During this period, a research organization will play the major role but several Taiwanese universities have joined the program management mechanism, business-model studies of service systems, anticipated-benefits evaluation and expert group discussions. Under the support of the Ministry of Economic Affairs, professors from multiple academic fields have provided many helpful suggestions and simulation results from business models and enterprise management. In addition to these professors, experts from each industrial field also joined

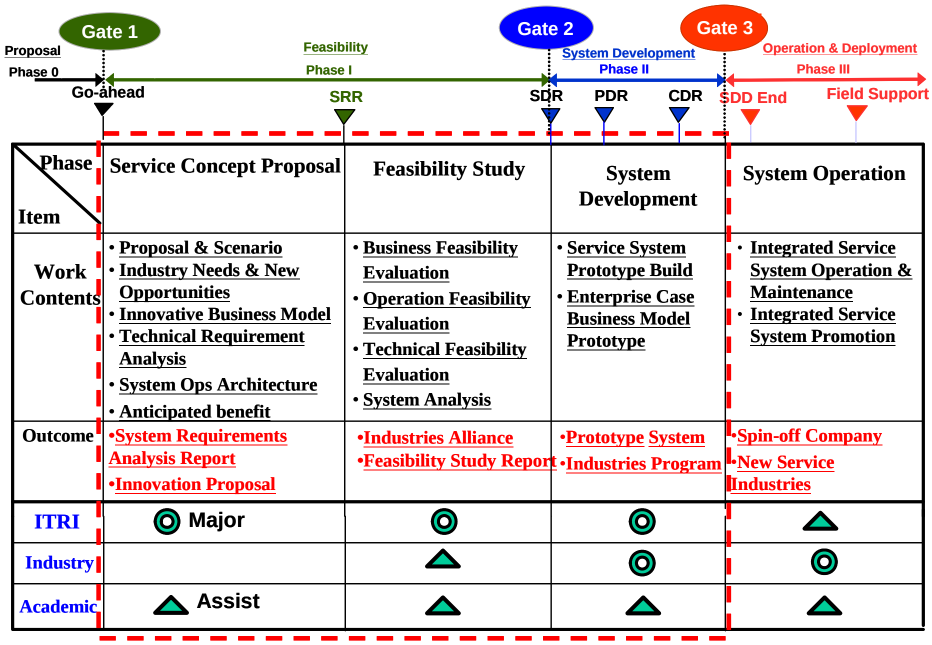

Fig. 4. Phase outcomes and entry/exit mechanism

the proposal discussions and outlined realistic customer needs. All these efforts can directly aid each organizational unit with a proposed system feasibility study, which can reduce the time needed for concept exploration. During phase 1, the evaluations of business, operational and technical feasibilities and system analysis are the major components. The outcome of this phase is to form an industrial alliance and compile a feasibility study report. As phase 2 is approached, the major content shifts to contructing a service-system prototype and examining a preferred-enterprise-case business-model prototype. Constructing a prototype system and creating an industrial program constitute the outcome of this phase. The enterprise and industry must engage in this period of work in order to make the system develop into reality. Finally, the integrated service system operation, maintenance and promotion constitute the major content of phase 3. Spin-off companies and the formation of new service industries are the outcomes of this phase. Industry will play the major role in this phase as the research organization shifts to a supporting position. The Knowledge-Intensive Service Industry Program implementation scope is focused on in the first three phases. In the system operation phase, the research organization and the government will assist the newly formed service industry with administrative support work and provide the necessary promotion.

VI. SYSTEM DEVELOPMENT APPROACH

The program office establishes the Knowledge-Intensive Service Industry Program system development platform with the application of systems engineering. The development approach is based on a system-integration application platform and a systems engineering infrastructure. As shown in fig. 5, the systems engineering infrastructure is situated in level 1 and constitutes the foundation for application technologies. The application laboratory in this level contributes methodologies and tools. The methodologies are derived from the handbook of the international council of Systems Engineering [5]; the tools are those used in each phase of the value-chain activities of an industry. Such activities include market analysis, R&D, design, engineering, manufacturing, logistics, marketing, sales and maintenance service. The software program INCOME can be used as a system process simulation tool. Software program such as Slate and Doors are necessary tools for requirement management (RM) to analyze customer needs. A tool such as Teamcenter is one example for use in performing Product Data Management work (PDM). As for manufacturing activities, computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM) tools can fulfill the requirements. Level 2 constitutes the system-integration application platform, which consists of a combination of e-environment and information-communication technology to form a general system-development technology platform, characterized mainly by modularization and automation. The platform in level 2

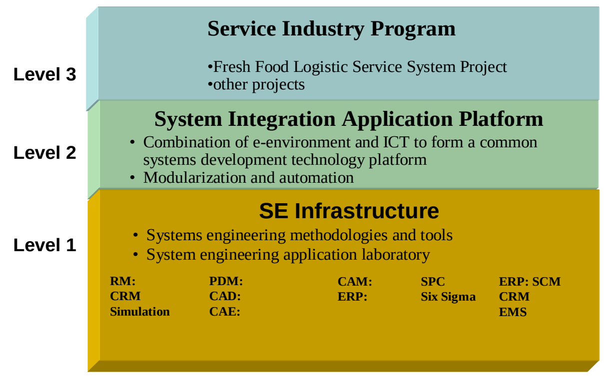

Fig. 5. Development approach for systems engineering application technology

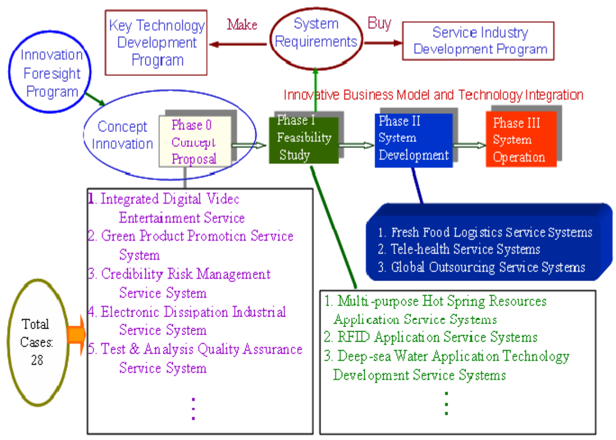

Fig. 6. Development programs in progress

uses methodolgies and tools provided by level 1. Various system-integration application platforms develop templates and tools which can feed back to the SE infrastructure in level 1. Thus, the Knowledge-Intensive Service Industry Program is an application resulting from the system-integration application platform and the systems engineering infrastructure. As additional projects enter this program, the cohesion and interaction among the three levels will gain strength. At present, the Fresh-Food Logistics Service System project in the Knowledge Intensive Service Industry Program has demonstated the value of this development approach.

VII. INTRODUCTION TO PROGRAM CASES IN PROGRESS

As of December 31, 2004, a total of twenty-eight projects have passed the program review from the earlier stage of concept innovation to entrance into the Knowledge-Intensive Service Industry Program, as shown in fig. 6. Sub-totals include eighteen projects in phase 0 for proposal study, Seven projects in phase 1 for feasibility study and Three projects in phase 2 for system development. Generally, the concept proposals can be integrated with technology from the Innovation Foresight Program during phase 0. Phase 1 is important for making the decision to make or buy from system requirements. In case of the decision to make, the project will seek key technological ingestion either from the Key Technology Development Programs within the Ministry of Economic Affairs or from abroad. Otherwise, enterprises can take this program case to seek funding from the Service-Industry Development Program for further business development. The Knowledge-Intensive Service Industry Program emphasizes the innovative business model and technological integration within Phases 1, 2 and 3. These projects demonstrate a portion of the core competiveness within research organizations and academia. With the help of this program, companies in Taiwan can develop new service-industry businesses and also create fruitful opportunities for domestic manufacturing industries. Most importantly, this program demonstrates the integrity characteristic of systems engineering. The integration of technology into knowledge-intensive service industries can create a profound influence, not only for Taiwan‘s economic development but also for its future industrial competitiveness.

VIII. CASE STUDY: FRESH-FOOD LOGISTICS SERVICE SYSTEM

By Integrating existing domain knowledge, including low-temperature handling, distribution and information technologies, the Fresh-Food Logistics Service System can contruct a knowledge-intensive service system for low-temperature fresh food. The objectives of this system can be summarized as follows:

1. Resolving the large temperature variation problem existing in logistics;
2. Using one general freight truck for multi-temperature distribution;
3. Improving the usage flexibility of the freight truck;
4. Reducing the capital investment for a refrigerating truck;
5. Obtaining real time temperature of the freight truck and food;
6. Improving inventory management and handling efficiency;
7. Reducing energy, labor resources and floor occupation.

In order to meet the aforementioned requirements, the necessary technologies and a multi-temperature eutectic refrigeration compartment are developed and applied. This compartment has an optimized design for temperature retention, eutectics, cold energy release, multiple capabilities, flexible size, RFID (Radio Frequency Identification) tags, smart temperature sensors, wireless telecommunication and other IT technologies. With these design features, the integrated eutectic cold box can obtain real-time freshness-monitoring functions. Computation simulation software is also developed for the stacking of a loader to satisfy the joint distribution requirement for both eutectic boxes and room-temperature compartments in a variety of sizes. Wireless telecommunication linkage viability is also developed for various customers' subsystem requirements.

The Fresh-food Logistics Service System encompasses storage, delivery, an information network, and a knowledge gateway for fresh food. The major component of this System is the logistics center, which connects both the supply and the sale ends of the supply chain. Logistics knowledge can be accumulated to strengthen service competitiveness through the Service's knowledge portal. By using a real-time business information network, the system can achieve operational transparency. A functional analysis of the present system examines the fresh-food storage, delivery, real-time information and knowledge disseminating functions. From the aspect of storage, the distribution center focuses on the retention of a low temperature, architectural, traffic-pattern, and spatial designs, and operations. The procedual design for low-temperature processing fulfills the freshness requirement for products and achieves the storage function from stocking of merchandise, examination, registration into the warehouse, selecting goods for packaging and low-temperature shipment. From the aspect of the fresh-food delivery function, the importance of multi-temperature fresh food centers on taste and controlling the temperature for maintaining the best quality. Due to the difficulty and unanticipated factors related to maintaining the desired temperature during delivery, it is very important to develop a practical solution for the delivery function.

From the aspect of the real-time information function, the business-information service is to provide data on fresh food and it's temperature in the merchandise delivery process. Real-time transparency of information such as business analysis, delivery status tracking and other functions can be achieved in this service. From the aspect of the knowledge-dissemination function, the supplier 'fresh food and hygiene, multi-temperature production and sales operations, and techniques such as multi-temperature eutectic joint distribution, temperature-monitoring technology, knowledge of multi-temperature home delivery operations and other functions at different stages of distribution and delivery can serve as an integrated knowledge service incubator in a multi-temperature field. With an effective application of the aforementioned factors, knowledge-intensive services can then be activated and new value can be created for the industry.

The As-Is and To-Be business models for the Fresh-Food Logistics Service System can be easily illustrated, as in fig. 7 and 8. The As-Is model shows that a traditional system relies heavily on telephones and facsimile machines for communication. This model also indicates that the operators need a fleet of different types of trucks which cannot manage food-storage temperatures well. This system can operate only regionally because the food cannot preserved in a hygienic condition during a longer transporation stage. Compared to the As-Is model, the To-Be model is built on the integration of suppliers, distribution centers, sales and customers [3]. In the To-Be model, the system can provide accurate warehouse management information and can save up to 50% of the floor area, 30% of the human energy and 30% to 50% of the energy efficiency. When establishing the international low-temperature logistics center of a local company with assistance from ITRI as an example, it is expected that this center will bring in 200 million NT in revenue in addition to operational expenses. The supplier's side originates in an alliance which includes agriculture, frozen and cold fresh-food manufacturers, food importers and others. The distribution center integrates both suppliers and sales by incorporating the ordering-chain information service, multi-temperature automatic manufacturing and sales system, and multi-temperature eutectic joint distribution with the assistance of network communication technology. On the basis of the industry's needs for multi-temperature fresh food service, techniques of whole-temperature logistics storage/distribution and process integration are developed by the use of an e-commerce system to improve the efficiency and quality of delivery through an intelligent transportation and delivery system and an integrated business information service. The Fresh-Food Logistics Service System includes three different types of customers: (1) individuals, (2) chain stores and (3) retailers. Much like a membership-only website, the system portal has multiple functions, such as entry login, information retrieval, e-news letters, downloads, expert consultations, hyper-linking, feedback and others. An industrial alliance consisting of enterprises and governmental and research institutes can provide consulting, testing and certification services with various expertise for customers.

IX. CONCLUSION

The use of new and ICT technologies along with a new business model is indispensable for the high added-value service industry. To meet this need and form new service

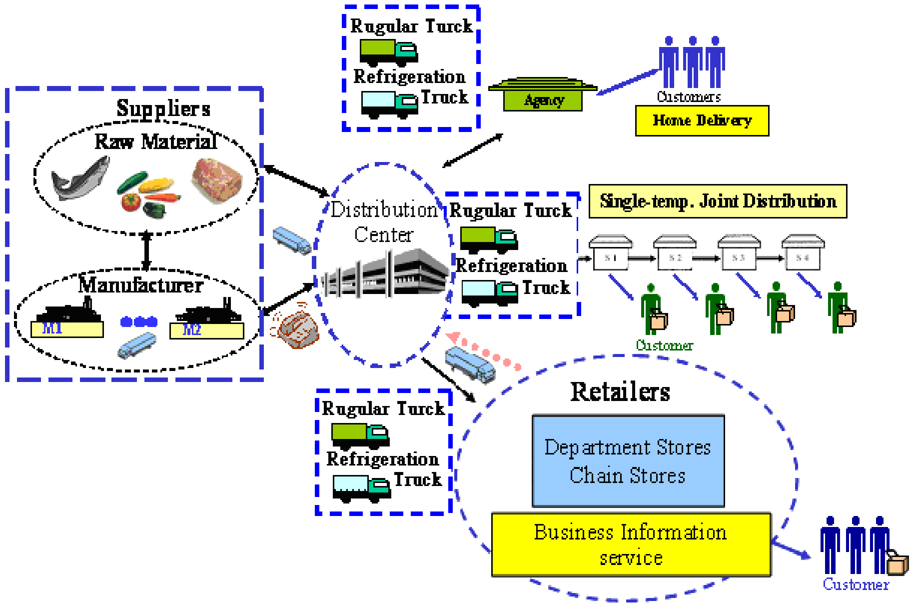

Fig. 7. Operational model (As-Is) for Fresh-Food Logistics Service System

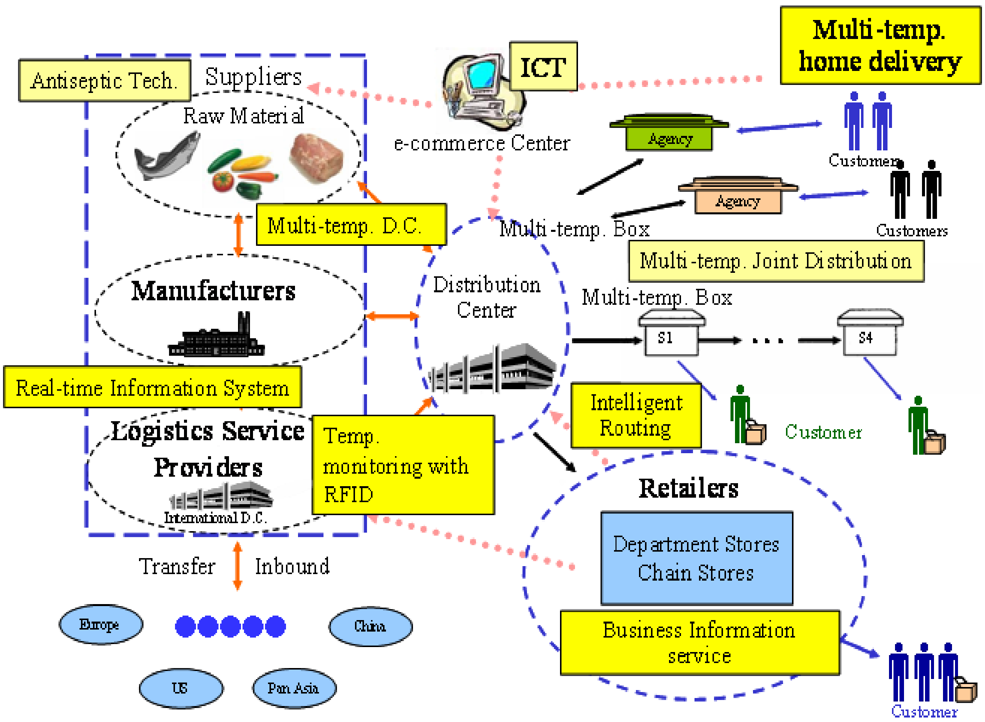

Fig. 8. Operational model (To-Be) for Fresh-Food Logistics Service System

industries, the Taiwanese government has created a new industry-development policy through the Knowledge-Intensive Service Industry Program. This Program needs interdisciplinary system integration capabilities from research organizations and academia to provide the service industries with the necessary innovation-technology tools and new business models. The selection criteria for this Program are based on system integration and service innovation in order to provide end-to-end total solutions in the service industries. A successful qualitative formula for knowledge-intensive service industries has been presented. With the introduction of systems engineering methdologies, the development mechanism of each service system project in this Program will progress through four different phases: (1) proposal, (2) feasibility, (3) system development, and (4) operation and deployment. The entry/exit mechanism in the scope of this Program has also been discussed. One program case, the Fresh-Food Logistics Service System project, has been discussed as a example of a systematic developemental approach to knowledge-intensive service industries. To verify the systems developed with technological integration and business models, further study should be conducted by simulation and verification of the prototypes.

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