

Solar Signage Business Model Design Using the EPSS Framework

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Abstract: The purpose of this study is to design a business model that generates profits by developing eco-friendly convergent products. This study proposes a new concept of solar signage in the digital signage system that helps carbon emission reduction. This study developed a solar signage business model using the eco-science methodology specialized in manufacturing servitization. Following the ecosystem platform service strategy (EPSS) framework of eco-science optimized for convergent industry service design, this study implemented service derivation, convergent ecosystem definition, and business model development. The developed business model was evaluated by 10 experts in the field. The business model obtained 43 points, which exceeded the standard commercialization decision cutoff of 35 points. This study's results imply that the business model is developed from an integrative perspective and defines the convergent industry ecosystem, a convergent knowledge service methodology, in digital signage. Moreover, through the business model, the perspectives on technological development can be expanded and the model can play an important role in carrying out new industry commercialization based on convergent technologies.

Keywords: solar signage; service design methodology; eco-science; business model



Citation: Kwon, H.-i.; Jeon, Y.-s.; Baek, B.-h. Solar Signage Business Model Design Using the EPSS Framework. *Energies* **2021**, *14*, 6960. <https://doi.org/10.3390/en14216960>

Academic Editors:
Krushna Mahapatra and
Vincenzo Bianco

Received: 7 July 2021
Accepted: 20 October 2021
Published: 22 October 2021

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1. Introduction

In 2021, the Kyoto Protocol expires, and the new climate accord of the Paris Agreement starts. The Paris Agreement adopted a bottom-up goal and suggested the range of a global average temperature increase of less than 2 °C based on the nationally determined contribution (NDC), which offers an attainable goal per country [1]. The temperature goal attempts to reduce carbon emissions by resolving climate change crises caused by manufacturing-centered industrialization. The Paris Agreement eventually aims at net-zero emissions by improving global climate change.

The electronics industry, producing products with high energy consumption, has been required to respond to the net-zero policy. One product category of the electronics industry regarding net-zero includes digital signage. Digital signage refers to a “remotely managed digital display, typically tied in with sales, marketing, and advertising” [2] (p. 1). Digital signage has been used in diverse fields of society along with information and communication technology (ICT) advancements.

Recently, increasing attention has been paid to digital signage with interests in smart cities for resolving rapid urbanization [3], the contact-free trend due to a pandemic [4], and media flexibility (online, offline, and hybrid) for message delivery [5]. The global market size of digital signage will continue to grow by 11.5% in the CAGR (compound annual growth rate) [6], and the growth is expected to last for years.

To respond to the movements on global climate change, this study proposes a new signage system that saves energy efficiently by focusing on the fact that digital signage consumes more energy than analog outdoor billboards in the consumption process. This new system is named “solar signage” and represents the integrated system of semi-transparent solar panels and digital signage.

In the current study, following the ecosystem platform service strategy (EPSS) framework of eco-science, a convergent service design methodology, a convergent industry business model was designed to facilitate the solar signage industry. The eco-science methodology as a knowledge-convergent design methodology that improves the limitation of the current service design is specialized to build the convergent business model in multi-industries. Using the eco-science methodology to design a solar signage business model, this study carried out the EPSS framework after reviewing the current design methodology and defining the solar signage industry. Specifically, this study implemented the processes from the derivation of solar signage services to the definition of the convergent industry ecosystem, and to the establishment of business model strategies for commercialization. Subsequently, this study tested the validity with 10 expert consultants in the industry and obtained valid evaluation results.

This study discussed a business perspective in the process of new technology development. Particularly, the business perspective is needed for convergent technologies and products regarding the net-zero policy. A technology bears meaning when it is used, and value is added in the use process. Eco-science is one of the optimal methodologies that reflect the business perspective in the new technology or product development process. This study expects eco-science to be applied to varying research development.

2. Theoretical Background

2.1. Eco-Science Methodology

Vargo and Lusch [7–9] predicted a paradigm shift from the goods-dominant logic to the service-dominant logic. In the past research on eco-science, value is created not by the production and supply of products but by customers' consumption. That is, the premise of the service-dominant logic regards customers as co-creators of value and is consumer-oriented and relational. The perspective of the service-dominant logic has shed light on the necessity of the manufacturing industry's servitization by recognizing value. Vandermerwe and Rada [10] proclaimed the manufacturing industry's servitization, the concept of which weighs more on services than on products and indicates the bundling of products, services, and supplemental elements.

One of the main commonalities between the service-dominant logic and servitization is the newly defined customer. Both the service-dominant logic and servitization focus more on the relationship and interaction with customers than on meeting customer needs, which were vital in the traditional industry logic.

The significance of the servitization of the manufacturing industry has been claimed by many researchers [11–14] and multiple approaches from the service design perspective attempted to employ servitization [15–18]. Although these approaches provide insights into designing innovative services, they show limitations by lacking business ecosystem perspectives [17,18], business operation strategies [15], and concrete frameworks [16].

The eco-science methodology proposes a framework that improves the limitations of the current service design methodologies [19,20]. The eco-science methodology supports the axioms of the service-dominant logic [9] and is defined by the EPSS framework based on the four core factors: ecosystem, platform, service, and strategy.

The first "E" of the EPSS framework indicates "ecosystem". The ecosystem factor supports business cooperation from the ecosystem perspective that leads the ecosystem to businesses. The "P" represents "platform" and consists of both tangible and intangible elements. The platform factor implies the modular structure that supports the interaction between actors and resources. The two "S"s symbolize "service" and "strategy". The core value of the EPSS framework lies in building the strategy to run specific service plans and a successful business.

The EPSS framework consists of phase, activity, and task. The phase represents core values and objectives. The phase includes four to five activities, and each activity is the execution unit to reach the objective of the corresponding phase. The task is an element for the activity and the lowest unit to execute the EPSS framework. The EPSS framework is

composed of 5 phases, 21 activities, and 37 tasks. The organization of the framework is displayed in Figure 1.

- Phase 1: Service derivation. Defines the problem through the analysis of internal and external industry statuses and draws convergent industry services through the diffusion and acceptance of innovative services.
- Phase 2: Convergent ecosystem definition. Defines the stakeholders that are needed to carry out the services drawn from the previous phase. Schematizes the convergent ecosystem by matching necessary roles for the services.
- Phase 3: Business model strategies. Designs the macro-business model from the convergent ecosystem perspective and defines the level of minimal service to be maintained between stakeholders. Improves service quality and strengthens the trust and cooperation between partners.
- Phase 4: Platform construction. Builds the integrative platform to provide convergent ecosystem services. The platform is executed in the order of analysis, design, implementation, and testing.
- Phase 5: Service execution. Verifies the drawn service and platform in testbeds. The efficiency is verified by analyzing economic impacts and consumer benefits.

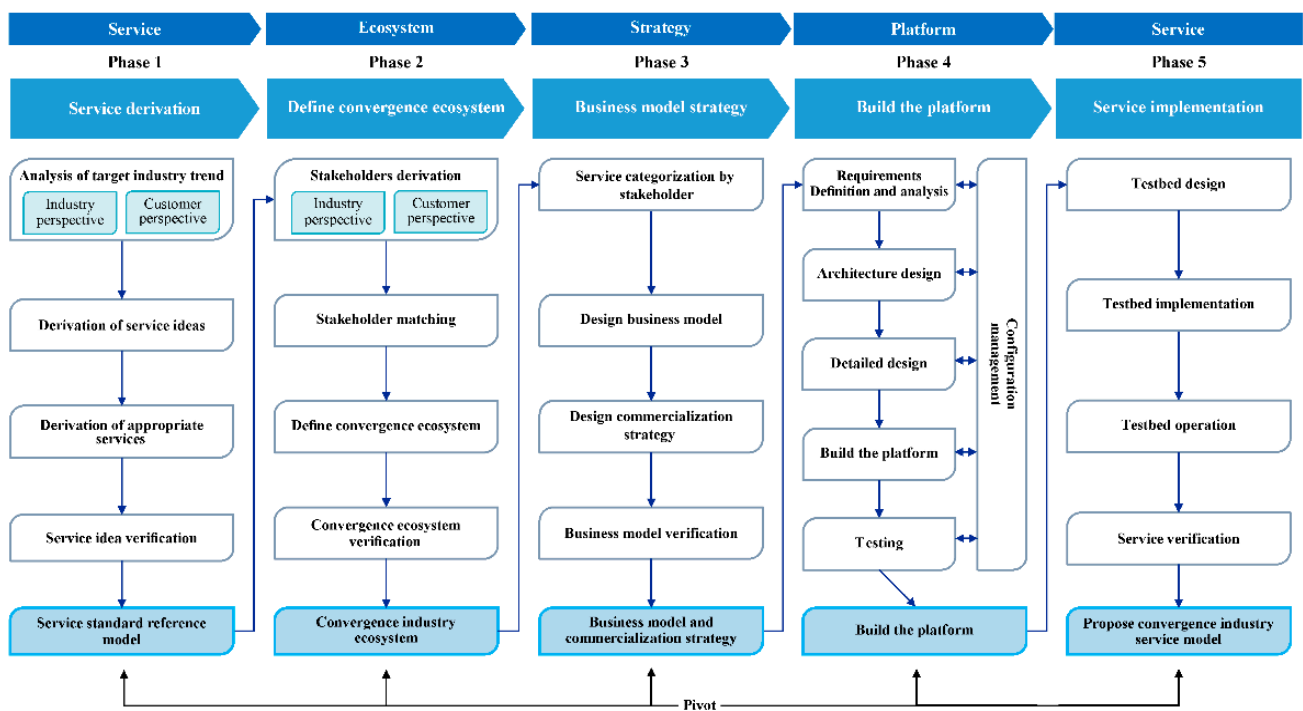


Figure 1. EPSS framework.

2.2. Solar Signage Industry

Movements for environmental protection are occurring not only at the national level. The net-zero policy by activating the Paris Agreement is not an option but a mandate. As an example, a carbon tax is regarded as an important policy that reduces greenhouse gas emissions in varying fields and regions [21]. A carbon tax was adopted by several European countries in the early 1990s. A total of 25 countries had adopted a carbon tax as of 2019 [22]. A carbon tax imposes taxes across all industries by directly affecting the industrial value chain. As such, the movements for net-zero are carried out at both the government and global levels. Many enterprises implement product concept design based on carbon footprints for carbon emission reduction.

However, the current product concept design has been limited to carbon emission reduction at the manufacturing level. Therefore, the reduction method is not sustainable

because no information about carbon emission reduction is available at the consumption level, resulting in deterring the efficiency of low carbon product concept design [23]. The amount of carbon emissions during product consumption is the same or more than the amount during production [24]. In turn, low carbon can be reached by considering the product lifespan cycle holistically.

Digital signage is a “digital billboard” through a digital display that replaces the current outdoor billboard system. From an academic perspective, digital signage is defined as “remotely managed digital display, typically tied in with sales, marketing, and advertising” [2] (p. 1). This definition applies not only to the advertising field but also to other broad fields, such as architecture and public information. As the old outdoor billboards convert to digital signage, this new means of signage has resulted in a product that consumes energy in the use process. In other words, digital signage is one of the industries that require innovation for low carbon emissions.

The energy-related topics have been little studied in digital signage research. Past research focused mainly on the effects of digital signage as an advertising medium [25–27]. Energy efficiency, or carbon emission reduction, has rarely been considered an important topic in research. However, the requirements for net-zero and carbon reduction are on the rise across all industries. The digital signage industry is not free from the requirements.

Although digital signage has yet to see any critical energy-related problems, preparations for upcoming risks are necessary as digital signage is growing at an exponential rate. Some factors facilitating the diffusion of digital signage include (1) an increase in the interest in smart cities where digital signage plays a key role in resolving urbanization issues [3], (2) expansion of the contact-free trend in a pandemic [4], and (3) high media flexibility for message delivery [5].

The convergence of the solar power system with digital signage can be an attractive combination regarding the net-zero requirement. The solar power system rarely requires maintenance and repair, and system design is simple. An independent execution system that provides power from micro watt to mega watt can be constructed [28]. Additionally, the recent development of transparent solar cells (TSCs) overcame the limitation of the current solar system, which requires a large installation size and increased the possibility of utilizing solar signage [29].

Therefore, this study offers the concept of solar signage and designs a business model that integrates digital signage with semi-transparent solar batteries. This study defines “solar signage” as “the one-body digital signage system that enables self-power generation by integrating digital signage with semi-transparent solar batteries”. Operating solar signage requires an architectural review for the power system that uses and manages the Internet of things (IoT)-based remote control system, self-generated power, sunlight, light pollution, quality of construction materials, and selection of the optimal location. Hence, the IoT, power conversion system, and construction industry are essential for the solar signage convergent industry. The conceptual map of solar signage this study proposes is displayed in Figure 2.

This study attempted to develop the above solar signage system and a business model that can be linked with a real business. For this purpose, this study implemented the development of a business model using the EPSS framework drawn from the eco-science methodology specialized in convergent industries.

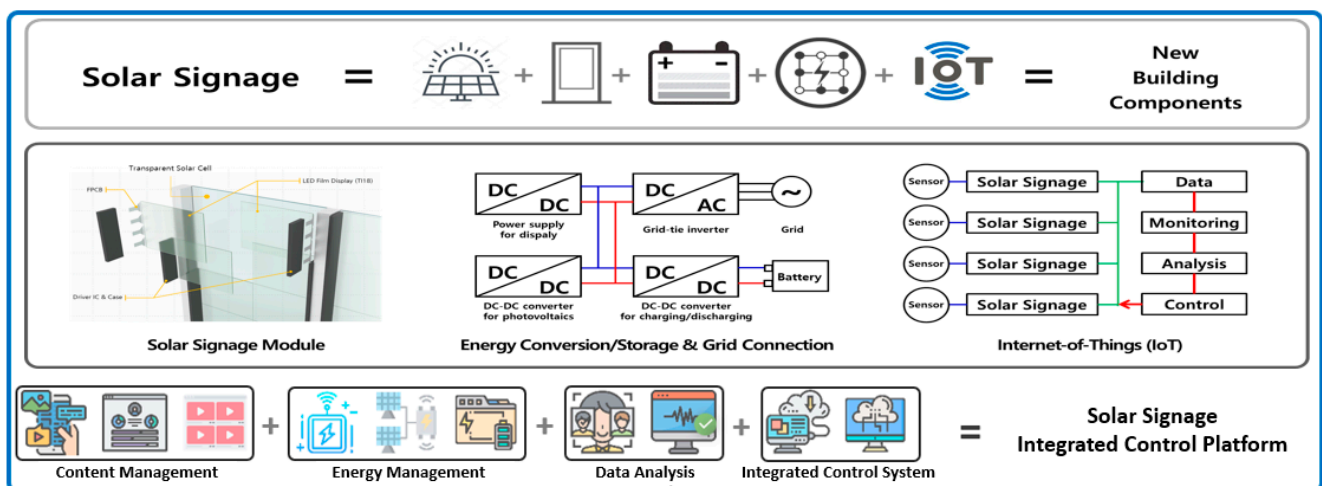


Figure 2. Conceptual map of solar signage.

3. Business Model Design for EPSS Framework-Based Social Signage Industry

The purpose of this study is to construct a business model for the convergent solar signage industry. The solar signage industry converges semi-transparent digital signage, solar batteries, and supplemental systems. The business model in convergent industries must be taken into consideration in terms of ecosystem units' value change. From this perspective, trust and cooperation between the nodes are crucial [30–33]. The EPSS framework is relevant for constructing the convergent industry business model in the view that the framework systemizes the construction of a cooperation system in stakeholders and recognizes customers as value co-creators. Therefore, to draw the solar signage business model based on the EPSS framework, this study implemented three phases from phase 1: service derivation to phase 3: business model strategy.

3.1. Phase 1: Service Derivation

This phase aims to derive services through four activities: (1) target industry status analysis, (2) appropriate service idea derivation, (3) relevant service derivation, and (4) service idea verification. Appropriate service means the comprehensive value creation process based on the appropriate technology. This study follows Akubue's [34], p. 38, definition of appropriate technology: "an approach to development that raises the productive capacity of the community through optimum use of existing skills and resources". The appropriate technology is used mainly to support developing countries [34,35]. Although not an innovative invention, the appropriate technology can be used for inducing innovation in a new field.

The service that uses the appropriate technology should be able to yield common value through interactions with customers as well as stakeholders. The appropriate technology is important in the cooperative ecosystem because the success of the cooperative industry business models is uncertain, and one entity cannot control all elements. Further, investing in the unverified cooperative ecosystem can be a burden for individual entities. As such burdens may induce partners' passive attitudes so that the burdens can be barriers to build a cooperative system within the convergent ecosystem, the entities should rely on the current capacity when participating in the ecosystem. Hence, to draw the appropriate technology, this study selected the current digital signage industry as a sample.

The analysis of the current digital signage industry was approached from the customer and industry perspectives. This study used a political, economic, social, and technological (PEST) analysis; focus group interviews (FGIs); and in-depth interviews. The analysis found that the demands by customers, advertising agencies, and digital signage owners differ from one another.

Based on the findings, three standards were established in developing services:

- Standard 1: The development is centered on the solar signage industry that enables semi-transparency and color creation.
- Standard 2: The development draws a service model that considers both the marketing targets and signage companies.
- Standard 3: The development draws a service model that considers solar signage and related industries.

Through a brainstorming process, this study drew a total of 21 specific services, 6 from the hardware perspective and 15 from the software perspective. The derived services were refined through a significance-timeliness analysis by 24 experts in the domestic solar signage industry. The results are presented in Figure 3.

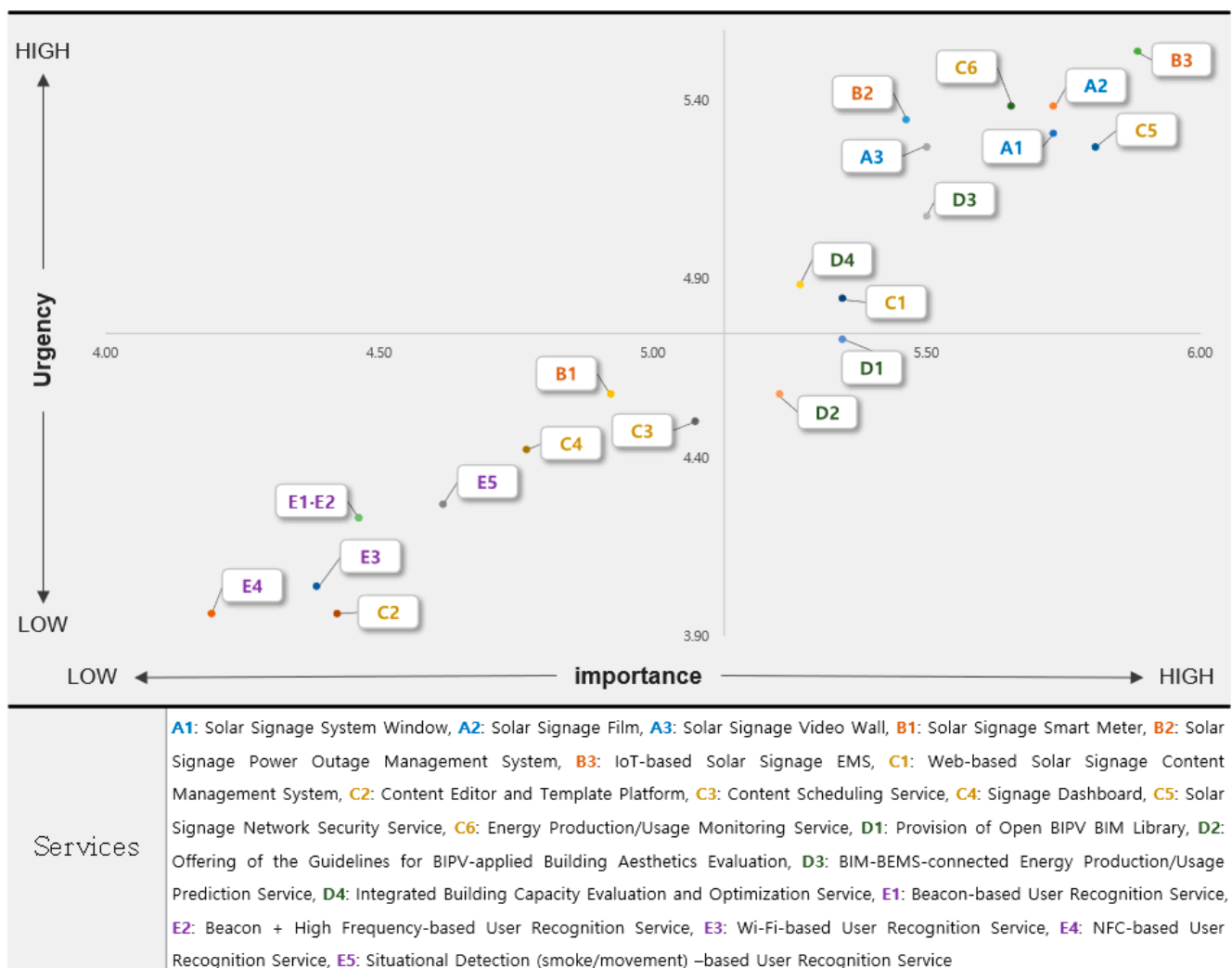


Figure 3. Analysis results of the derived service significance-timeliness.

From the results of the service significance-timeliness analysis, this study integrated 21 services. Based on the integration, this study drew the prototype of the business model. The service model named “smart space solution” represents the model that designs any space as an intelligent space. For example, in a smart home, the windows can be replaced with solar signage so that necessary information can be displayed on the windows.

Moreover, solar signage is linked with other IoT devices so that the voice recognition system can control all devices. These devices are run using energy generated by solar signage. Except for some transparent areas (e.g., windows), all walls can increase energy efficiency by attaching non-transparent solar batteries. This service model can be customized to diverse spaces, such as smart offices and smart cities. The key to this service

model is to provide integrative services from smart space consulting to installation, and to post-installation warranty service. Anticipated clients for the service are public and private sectors. These sectors include cooperative stakeholders who provide both software and hardware services.

The prototype of the service model is shown in Figure 4.

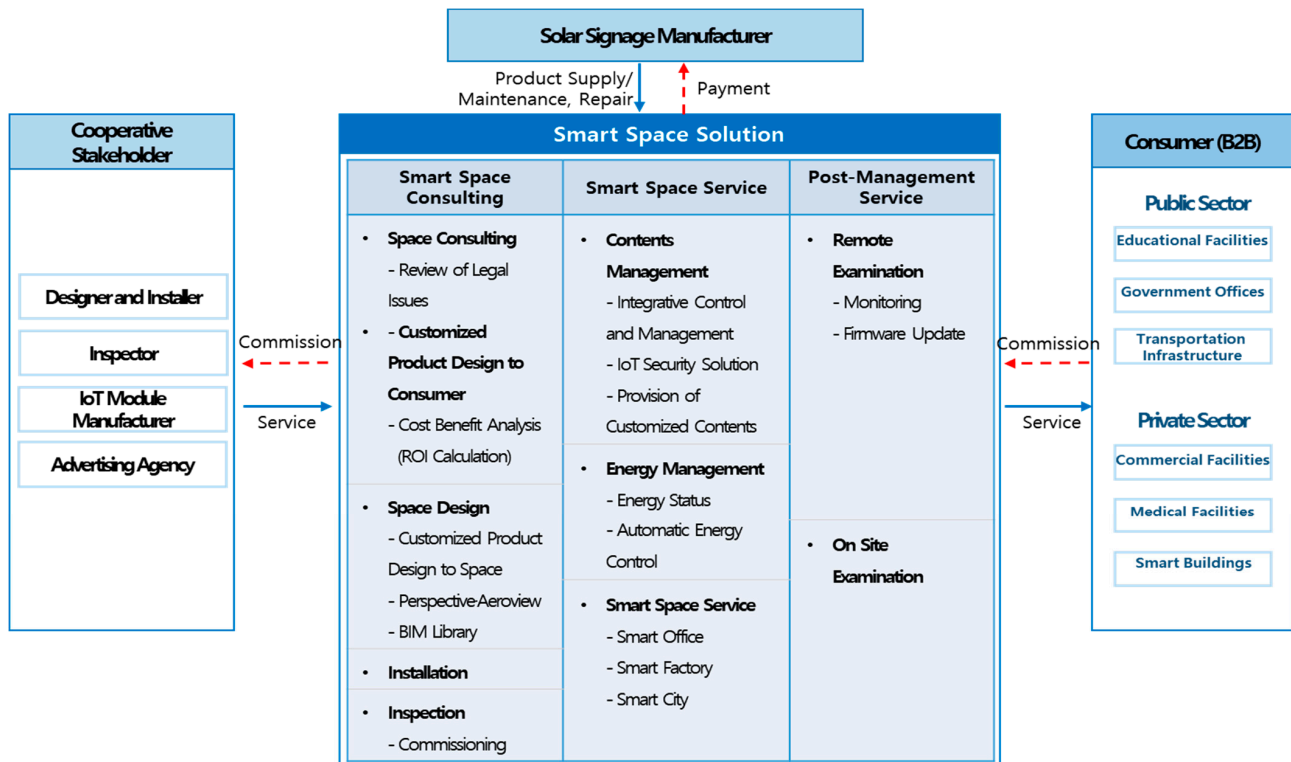


Figure 4. Service prototype.

3.2. Phase 2: Definition of the Convergent Ecosystem

The convergent ecosystem using the EPSS framework is similar to GVC (global value chain). Gereffi et al. [31] suggested the concept of GVC, which approaches not in terms of the value chain at a single enterprise level but in terms of the value chain at a national industry level. Gereffi et al. [31] employed Arndt and Kierzkowski's [36] term "fragmentation" to explain GVC. Gereffi et al. [31] argue that the fragmentation of production procedures in a value chain forms a new value chain through the networks of enterprises in multiple countries. This fragmentation idea started by finding that outsourcing non-core parts of manufacturing and services separately is better than outsourcing them all in one enterprise.

Both the convergent ecosystem and GVC state that approaching value chain innovation is not from internal innovation but cooperation with external enterprises. However, the convergent ecosystem differs from GVC in that each ecosystem builds a new convergent industry through stakeholders' skills and service convergence. Specifically, the convergent ecosystem in this study defines a new value chain by transferring the non-existent components in the current industry's value chain to the convergent industry value chain.

In phase 2, this study implemented stakeholder derivation, stakeholder matching, convergent ecosystem definition, and convergent ecosystem verification. First, the skills required for the service based on the drawn prototype were listed. Second, the stakeholders who provide the skills were listed. The drawn stakeholders are displayed in Figure 2. In service matching activities, resources required for implementing specific services were classified. Then, we listed the names of enterprises or organizations to cooperate with. However, as we were in the phase of researching related products and aimed at drawing

a convergent business model conceptually, we skipped the service matching phase that defined the entities of specific businesses.

The definition of the convergent ecosystem can be schematized based on Basole and Rouse’s [37] service value networks (SVNs). Based on the concepts that suppliers produce value and make linear delivery to customers, the current value chain has not been pertinent for application to the EPSS framework, because it is difficult for the value chain to explain the complexity and various relational characteristics between stakeholders in the industry. SVN explicates that value is created not at the relational level but the network level and that stakeholders in the networks gradually contribute to value creation [37,38].

Consumers are recipients as well as co-creators of value. When the value reaches consumers, it reaches the highest point. The entities of value actions in the SVN model consist of five elements: tier 1, tier 2, auxiliary, service providers, and consumers. The role of each entity is shown in Table 1.

Table 1. SVN entities’ roles and content.

Entity	Content	
Customers	The entities and end-users who consume and experience the value of all activities in service value networks Service providers are eventually benefited when customers are satisfied and pleased with the service	
Service providers	The actors who provide the service (or a bundle of services) for customers to experience, use, and consume the wanted and expected value The focal actors who interact with customers in the service value networks	
Enablers	Tier 1	Delivers service providers products and services directly
	Tier 2	Provides Tier 1 enablers with products and services
	Auxiliary	This is the essential component in the entire ecosystem not limited to only one industry and influences either partial networks or all actors.

The convergent ecosystem using SVN defines the digital signage industry ecosystem (AS-IS) as the current industry. Its structure is presented in Figure 5. This definition is derived from the notion that (1) there exists no solar signage in the current industry ecosystem and (2) the main device to conduct service functions is digital signage.

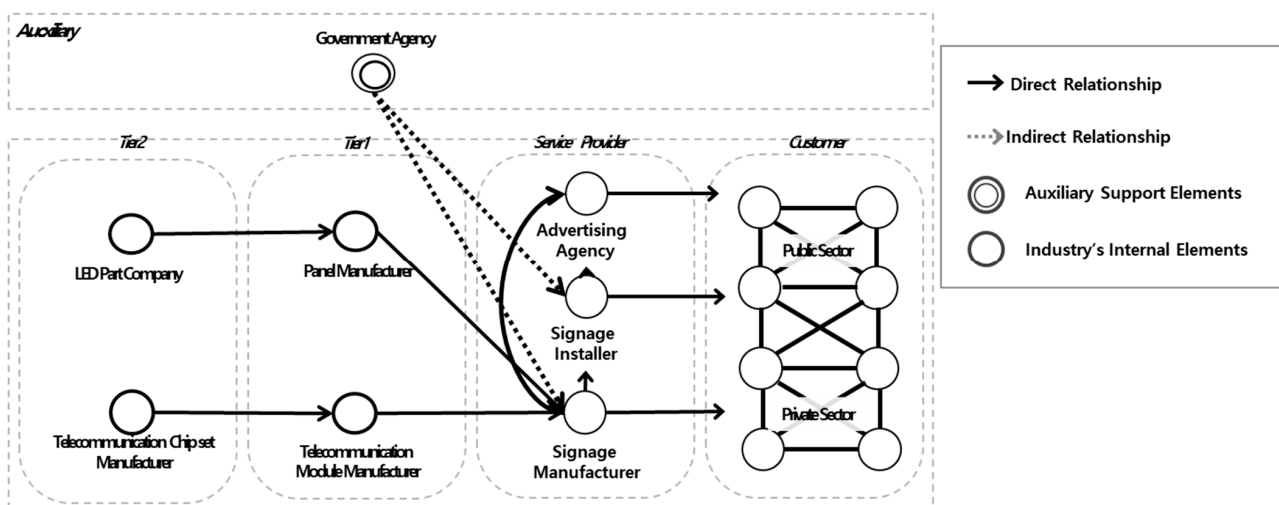


Figure 5. AS-IS model.

Tier 2 enablers include light-emitting diode (LED) part companies and telecommunication chipset manufacturers. Tier 1 houses digital signage panel manufacturers and telecommunication module manufacturers. Auxiliary enablers encompass government agencies that process deregulation and subsidiary at the industrial level. Service providers indicate signage manufacturers, installers, and advertising agencies. Customers can be divided into public and private sectors.

As seen in Figure 6, the new ecosystem (TO-BE) from the construction of the solar signage convergent industry can be created. The new system views that solar signage plays the role of eco-friendly and intelligent construction materials that go beyond digital signage as an information delivery medium.

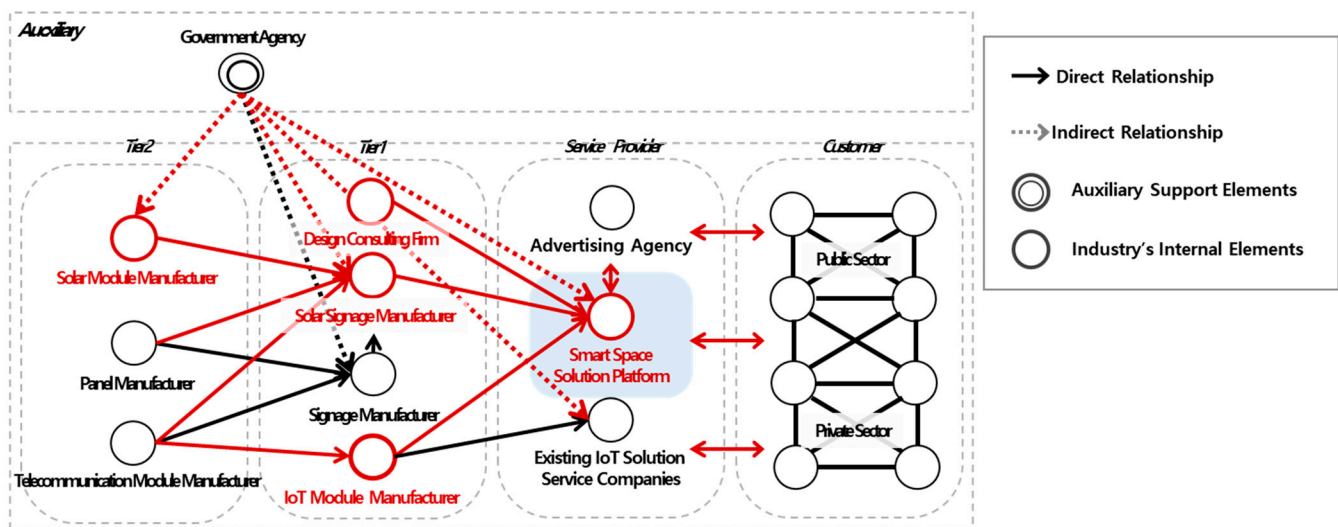


Figure 6. TO-BE model.

Tier 2 includes a solar power module, panel, and telecommunication module manufacturers. They cooperate with solar signage, digital signage, and IoT module manufacturers. Design consulting firms are newly added to tier 1. The auxiliary enablers include government agencies. Service providers include advertising agencies, smart space solution platforms, and current IoT solution service companies. Consumers are divided into public and private sectors.

3.3. Phase 3: Business Model Strategy

The convergent industry business model differs from the existing industry business model because (1) the convergent model should consider the cost structure and revenue flow that was not considered in the current industry and (2) the proposed value converts into new forms. In phase 3, the design and strategies for the convergent business model are established and multiple verifications are conducted in strategy design, business model design, roadmap design, and business models. In this study, however, strategy and roadmap designs were not implemented because we did not have participating business entities. We developed the convergent business model conceptually. In the EPSS framework, the business model was designed based on the Business Model Canvas (BMC), suggested by Osterwalder and Pigneur [39]. Figure 7 displays the derived model.

The core value of the proposed business model is to reduce the energy usage of a building as well as to reconsider the residents' satisfaction with dwelling spaces. The business model converts smart homes, smart offices, and any other spaces in the private sector to intelligent spaces so that they deliver value to service users. The model attains net-zero by using self-generated electricity as an energy source. As a result, the business model enables the amount of electricity digital signage uses to be reduced, contributing to energy savings.

The business model operates in the form of a smart space platform. The model can be classified into front and rear interactions. The service preparation process for consumers is formed during the rear interaction between the platform and the partner. A company manufactures solar signage by receiving digital signage, solar modules, and telecommunication modules.

Key Partners <ul style="list-style-type: none"> • Solar Signage Manufacturer • IoT Module Manufacturer • Design Consultant • Advertising Agency 	Key Activities <ul style="list-style-type: none"> • Smart Space Consulting <ul style="list-style-type: none"> - Space Consulting - Space Design - Installation/Inspection • Smart Space Service <ul style="list-style-type: none"> - Content Management - Energy Management - Smart Space Service • Post-Management Service <ul style="list-style-type: none"> - Remote Examination - On Site Examination 	Value Propositions <ul style="list-style-type: none"> • Improvement of residential environment and quality of life through smart space construction • Contribution to vitalizing domestic signage/solar industry ecosystem and strengthening global competency • Response to global climate change policies through the reduction of building energy usage 	Customer Relationships <ul style="list-style-type: none"> • Membership 	Customer Segments <ul style="list-style-type: none"> • Public Sector <ul style="list-style-type: none"> - Government Office - SOC • Private Sector <ul style="list-style-type: none"> - Medical - Office Building - Apartment - Commercial
Key Resources <ul style="list-style-type: none"> • Platform Construction and Operation Resources 	Channels <ul style="list-style-type: none"> • Offline Channel • Online Channel 			
Cost Structure <ul style="list-style-type: none"> • Design Consulting/Installation/Inspection Costs • Module Supply Costs • Platform Maintenance/Management Costs • Service Warranty Costs • Other Business Operation Costs 		Revenue Streams <ul style="list-style-type: none"> • Product/Service Intermediation Commission • Smart Space Service Charge • Outdoor Advertising Revenue 		

Figure 7. Business model canvas.

The manufactured solar signage is delivered to architecture and installation companies. They design the location of solar signage following the purpose of space and usage. An inspector reviews and tests whether the architects and installers install it as designed and the product works normally. The module manufacturer for IoT modules based on the spacing purpose and the advertising agency for contracts and content production are included in the rear interaction.

The front interaction encompasses the economic interaction between the consumer and the platform. The platform provides space consulting, installation, IoTization, and management services regardless of the public and private sectors. Consumers pay installation and service costs for the provided services. Specifically, smart city and smart office services are provided for the public sector. Smart homes, smart offices, and advertising services are provided for the private sector. To protect consumers from the cases that some products may not work as warranted and consumers may experience losses due to malfunctions, the platform registers for warranty insurance for the service. The insurance company provides warranty service when the filed claims are accepted. The conceptual map detailing the business model is shown in Figure 8.

To verify the derived business model, the BMO (Bruce Merrifield-Ohe) evaluation was conducted among experts and business consultants in the industry. The BMO evaluation is

a screening technique to select an attractive item in the phase of planning a new business and implemented in three phases. Phase 1 concerns the attractiveness of the market for the business. Phase 2 evaluates the relevancy of the company. Phase 3 implements the evaluation process for the probability of business success based on the data from the first two phases.

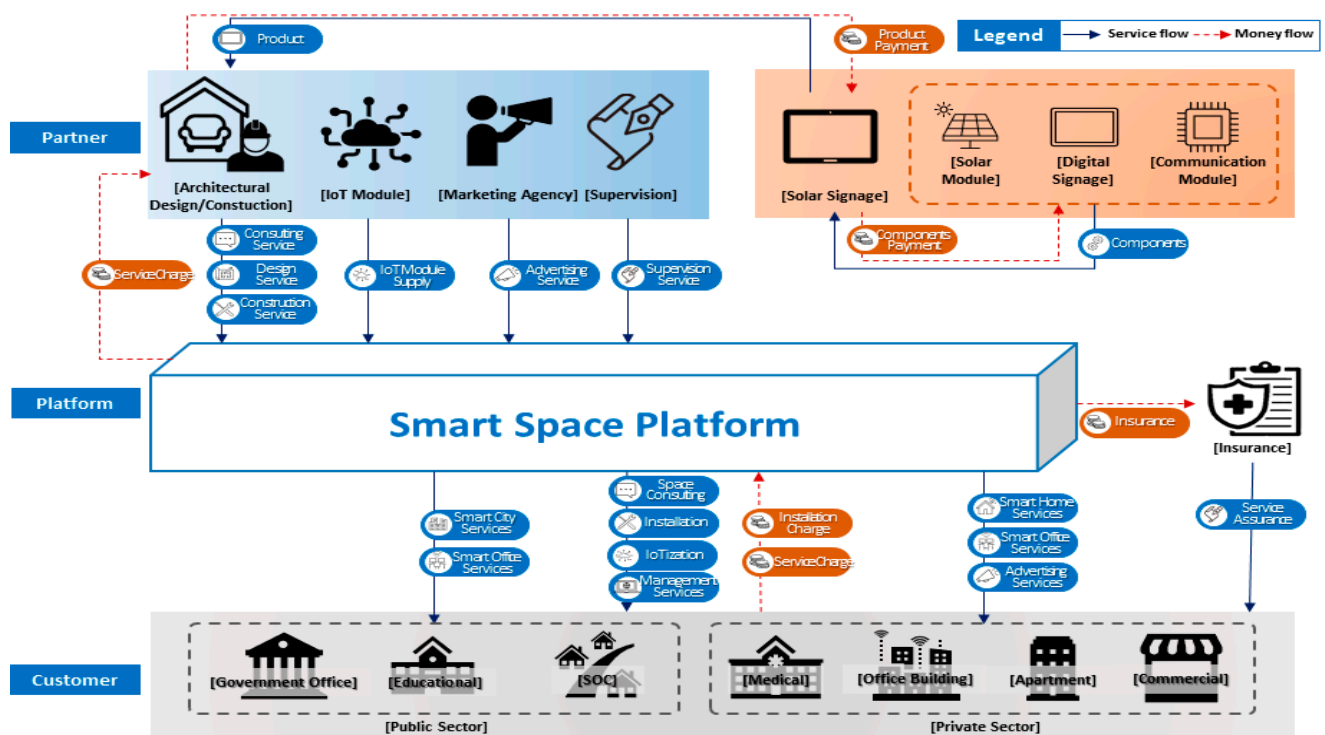


Figure 8. Specification of the business model.

Since there were no real entities that carried out the business model in the current study, we evaluated only the attractiveness of the business market in the first phase. An evaluation of industry data was conducted for the solar signage market in the digital signage industry. Marketsandmarkets [40] rated five out of five and foresaw the global market size of digital signage reaching an estimated \$27.8 billion in 2026. The report also rated five out of five and predicted growth by 11.2% in the CAGR between 2021 and 2026. Ten experts in the industry and business consultants evaluated all items and the sum of the evaluations drew an average of 43, which exceeded the standard cutoff of 35 points. The results indicate that the business model drawn from the current study verifies an entrepreneurial possibility. The evaluation results by experts are shown in Table 2.

Table 2. BMO evaluation results.

Evaluation Items		Perfect Score	A	B	C	D	E	F	G	H	I	J
Phase 1	Market Size	10	8	7	8	7	8	8	8	7	8	7
	Growth Potential	10	5	5	5	5	5	5	5	5	5	5
	Competitiveness	10	8	6	8	7	8	6	8	8	7	5
	Risk Segmentation	10	9	7	8	8	7	7	8	8	7	7
	Industry Reorganization	10	10	10	8	9	7	8	10	8	8	8
	Social Superiority	10	7	8	8	7	6	7	8	7	7	6
	Total	60	47	43	45	43	41	41	47	43	42	38

4. Conclusions

This study designed the solar signage industry business model using the EPSS framework. Solar signage is the digital signage system that enables self-power generation

integrated with semi-transparent digital signage, solar batteries, and auxiliary systems. Considering the necessity of other supportive industries for solar signage, the approach is not from a single unit industry but a convergent industry perspective.

In this view, the EPSS framework of the eco-science methodology used for the business model design is specialized in the convergent industry. The EPSS framework systemizes the construction of the cooperation system between stakeholders and improves the problems of the current service design methodologies, such as the lack of specific frameworks and business strategies. This study designed the convergent industry business model by implementing the procedures from phase 1: service derivation to phase 3: business model strategies based on the EPSS framework.

In phase 1, three service derivation standards were established by analyzing the target industry, and 21 specific services were drawn. The derived services were integrated into the final five services by refining the services in consultation with experts. Based on the drawn services, a prototype of the business model was developed. The developed prototype was named “smart space solution”. In phase 2, stakeholders who can provide five services were drawn and the convergent ecosystem was defined by the stakeholders. The convergent ecosystem was defined using the service value networks. The convergent ecosystem was differentiated from others by comparing the present digital signage industry ecosystem with the solar signage industry ecosystem. Lastly, in phase 3, the convergent business model was drawn. A visualization was proposed by showing how ecosystem stakeholders conduct the front and rear interactions through the developed business model.

This study has several limitations. First, this study did not provide data from solar signage products because solar signage is in the development stage. Solar signage development is at the level of the beta prototype at present. It will take a while to produce a complete solar signage product. Therefore, at the current level, only predictive figures of the business model can be suggested. However, the responses from the industry experts and business consultants indicate that a newly developed product has a positive market outlook.

Until the non-transparent solar cells secure a sufficient level of electricity generation, the solar signage industry can manufacture a new product by replacing some portions of the current signage or designing portions of the signage product as non-transparent solar cells. These attempts enable correct problems of new products and build a foundation for developing advanced products. At the beginning of the stage, the business model set an initial market entry strategy by targeting the public sector to experiment with the products.

New technologies and products tend to be adopted by the market slowly due to many risks. Being not selected by the market means that the product is not practical or attractive. Some technologies have innovated human lives, but some were even not introduced to the market or remembered. Specifically, only valuable innovations are adopted by the market.

At the beginning of development, new technology and products cannot replace the currently dominant ones in the market. A good example is hydrogen vehicles. Many people believed that hydrogen vehicles would replace gasoline vehicles. However, changing and mileage is not as effective as the current gasoline vehicles. These obstacles can be deterrents for consumers' choices. As such, in the development of new technology, both short-term and long-term plans should be considered in the inception stage.

The business model proposed in this study considers the business aspect in the technology development stage. The EPSS framework used in this business model develops products and technologies in the optimal way in which engineers and chief officers design and market together for a successful outcome. As discussed above, a new product or technology can have value not only by the development itself but also by market adoption. The research and development costs can be compensated by market profits. The profits can lead to the development of related products and technologies. Consequently, the development of new technology should include a business perspective.

This study contributed to the field by initiating the discussion on the new system of solar signage and evaluating its efficiency by applying the eco-science methodology, a

service design methodology specialized in the convergent industry. Specifically, using the EPSS framework of the eco-science methodology, a systematic business model derivation process was carried out. This study proposed ideas for diverse stakeholders to cooperate with one another within the business model from the business ecosystem perspective.

However, whether this framework can be utilized effectively in a real business needs to be verified by repeated applications and tests. In the times that diverse industry fields are integrated and converged, proposing a business model from a macro and integrative perspective at the industry ecosystem level can advance service design methodologies. Future research can verify the efficiency of the eco-science methodology by designing many business models of the convergent industry and modify and improve the methodology through feedback received in the design process.

Author Contributions: Conceptualization, H.-i.K.; methodology, Y.-s.J. and B.-h.B.; formal analysis, Y.-s.J. and B.-h.B.; investigation, Y.-s.J. and B.-h.B.; writing—original draft preparation, Y.-s.J.; writing—review and editing, H.-i.K.; supervision, H.-i.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea) under grant 20003580 and the National Research Foundation (NRF) grant funded by the Ministry of Science and ICT for First-Mover Program for Accelerating Disruptive Technology Development (NFR-2018M3C1B9088457).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This work was supported by the Industrial Technology Innovation Program (20003580, Manufacturing Service Convergence, Business model Methodology, Customer Experience Management, AI, Service Design).

Conflicts of Interest: The authors declare no conflict of interest.

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