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Business Model Development for Automatic Quality Inspection System of Temporary Structure Elements

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Abstract: For reusable Temporary Structure Elements such as scaffolding and temporary supports, quality control tasks are currently carried out through visual inspections by quality management workers and subjective judgments. Regarding quality tests based on the KOSHA(Korea Occupational Safety & Health Agency) system, only three pieces are sampled regardless of the quantity received at the site. On the other hand, although there is ongoing technological research on an automatic quality inspection of temporary structure elements, relevant stakeholders' introduction of such systems is hindered by issues such as cost. Therefore, this study aims to review a business model for introducing a quantitative and automated quality inspection system for reusable temporary structure elements. The study intends to propose application methods for each component according to a template and establish the business model by conducting interviews and collecting basic data for each template component. The results of this research are expected to serve as a foundation for implementation and expanding the adoption of quality management for temporary structure elements using smart technologies in the future.

Key words: Temporary Structure Elements; Automatic Quality Inspection System; Business Model

1. INTRODUCTION

1.1. Background and Objectives of the Study

In 2020, out of a total of 733 fatal accidents, approximately 42%, or 308 incidents, occurred in the construction industry, and about 28%, or 205 incidents, were attributed to temporary construction structures [1]. Notably, in the collapse incident at the Sadang Comprehensive Sports Centre in 2015, there were 11 industrial injury victims. In the same year, incidents like the collapse of the Yongin Bridge led to 35 industrial injury victims and fatalities [2]. The audit results from the Board of Audit and Inspection identified temporary steel structures made from defective elements as a common cause. Upon investigation of the thickness, elongation, and strength of temporary structure elements, it was found that they were approximately 60-77% below the standard. A survey of 116 samples of temporary structure elements from nationwide construction sites revealed that about 54% of the elements were unsuitable for use. Quality issues with temporary structure elements arise due to damage or deformation leading to a reduction in strength during reuse. The problem is exacerbated by the fact that quality testing, according to the 'Guidelines on Performance Standards for Reusable Temporary Structure

Elements (KOSHA, 2018)', samples only three pieces per type regardless of the quantity delivered at the site, resulting in insufficient discrimination [3].

Meanwhile, in order to eradicate industrial accidents that occur persistently, a significant industrial accident punishment law has been established as a systemic measure for ensuring safety. This law imposes fines, such as 750,000 USD, in the event of a fatal accident, leading companies to recognize the increased necessity of establishing safety management systems. Apart from this fine under the new law, safety accidents also result in cost losses for companies. For example, in the 2022 Hwajeong i-Park collapse incident, the estimated loss for reconstruction, compensation, and other expenses for accident recovery were in the range of 200~300 million USD [4].

In this way, construction industry accidents are considered societal disasters that affect the continuity of business operations by causing corporate punishment [5]. Therefore, safety systems are essential. Particularly, in the case of temporary structure element, which account for approximately 67% of construction industry fatal accidents [1], the need for a safety system is even more critical.

Based on this background, the research project 'Smart Safety for Temporary Structures' is being conducted as a constituent technology of 'Smart Construction Technology Development Project ('20~'25)' by MOLIT (Ministry of Land, Infrastructure and Transport). This project aims to improve the low productivity and high accident rate in the domestic construction industry and enhance the national competitiveness, with the goal of reducing the construction industry accident rate by more than 25%. The 'Automatic Quality Inspection System for Temporary Structure Element' under the 'Smart Safety for Temporary Structures' research project is being developed as part of this initiative. While the quality control of reusable temporary structure elements is currently carried out through visual inspections by on-site workers and subjective judgments, the application of this technology is expected to enable objective and quantitative assessments based on standardized criteria, allowing for enhanced safety and introducing automation technology. However, companies engaged in the leasing of temporary structure element, where the quality control is performed, may face constraints due to cost issues. The investment of funds is crucial for ensuring the safety of temporary structure element. Therefore, there is a need to address and complement the market structure in this regard [6]. Hence, this paper aims to propose a business model template to examine and establish the necessary components for applying the automatic quality inspection system for temporary structure elements in realistic field.

1.2. Study Scope and Methodology

This study proceeds in four major steps to achieve its research objectives (Figure 1). First, a review of prior research on temporary structure elements and business models are conducted. Second, interviews and data investigation are carried out based on the components of the business model. After conducting interviews to collect data on various opinions about how to manage temporary structure elements, data was investigated when objective index values were needed,. Third, a business model canvas is filled out with this information. Fourth, conclusion about the business model is summarized.

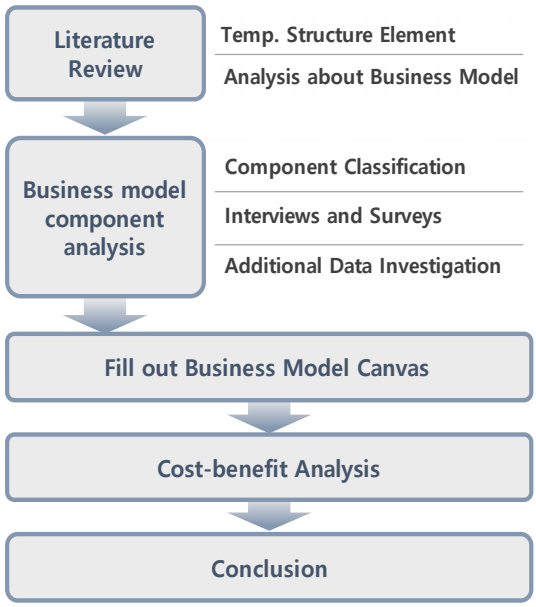

Figure 1. Research Flow

2. LITERATURE REVIEW

2.1. Policy and Technology about Temporary Structure

Research on temporary structure elements in Republic of Korea can be classified into two categories: studies on domestic and international policies related to temporary structure elements and studies on the development of quality management technology.

Firstly, there is a study that compared and analysed domestic and international quality inspection systems related to temporary structure elements [7]. It revealed that the operation of systems for ensuring the quality of reusable temporary structure elements is inadequate. By referencing Japan's comprehensive management guidelines, the study emphasized the need for practical and comprehensive quality management. Additionally, the study identified the necessity of developing and disseminating inspection criteria and testing methods to secure the quality and safety of reusable temporary structure element.

Another study [8] that developed grading criteria for temporary structure elements examined key factors influencing condition assessments. After conducting numerous performance tests at accredited testing institutions, the study presented threshold values for judgment criteria based on influencing factors using a statistical analysis framework. This proposed the developed and improved grading criteria for temporary structure element.

In a study proposing institutionalization measures for introducing smart quality management for temporary structure elements [9], the need for institutionalization to use an integrated quality management platform for temporary structure elements was emphasized. By suggesting institutionalization variables and analysis model measures to improve current quality management-related problems, each variable affecting institutionalization was reviewed, and a strategy was suggested.

A case study on the development of software for evaluating and managing the quality of temporary structure elements [10] found that evaluation and management systems for the installation and inspection of temporary structure elements are not commonly used. The study is working on developing software for quality evaluation and management of temporary structure elements to supplement management tasks performed in different ways on construction sites. The aim is to digitalize quality evaluation and management tasks, enhancing timeliness, transparency, efficiency, and enabling comprehensive record management.

Another case study [11] is researching three damage detection technologies for assessing the grades of temporary structure elements and developing an integrated system to display the results. Laser profiler, Magnetic Flux Leakage (MFL) sensor, and Explainable Artificial Intelligence (XAI) algorithm technologies are utilized to detect major structural damages such as deformation, cracks, and corrosion. The collected damage data through these technologies are visualized through 2D images and 3D Point Clouds, stored, and managed in a database.

In summary, research on temporary structure elements has mainly focused on institutional measures and technological development.

This study aims to explore business models for applying new technologies in practice for quality management.

2.2. Business Model

To review prior literature on business models for introducing new technologies, two areas are investigated: business models for new technology and business model canvas.

There is a research case [12] that proposed a business model to introduce a construction equipment guidance system and evaluated the effectiveness of its application. The study presented the system application process, identified stakeholders' benefits, and demonstrated through on-site tests that the system could enhance productivity in excavation work.

In the field of IT new technology, there is a research case [13] that provided a development methodology for business models. The study presented the structure and detailed contents of the methodology for developing business models for IT new technologies and applied it as a case to the mobile internet environment.

An analysis of strategies for the activation of the home network industry is found in a research case [14]. In this case, the study analysed home network technology and products to understand the value chain. Subsequently, it examined the growth potential of the domestic market, analysed business models

for telecommunication companies, contractors, content providers, and electronics companies, respectively. The study also identified revenue-cost structures and analysed business strategies and competitive advantages.

In summary, the prior research on business models encompasses some cases for introducing new technologies. Nevertheless, research gap is identified from the literature review. The template for introducing new construction-related technologies was scarcely reported. Therefore this paper presents a business model canvas for that subject, presenting key components and related contents to consider for business.

There are various templates available for creating business models and reviewing components. One commonly mentioned template aligns with the components presented in "Business Model Generation" by Osterwalder (2010), confirming similarities with the components commonly mentioned [15].

The Business Model Canvas consists of nine components: Customer Segments, Customer Relationships, Channels, Value Propositions, Key Activities, Key Resources, Key Partners, Cost Structure, and Revenue Streams [16]. This study aimed to define a business model for the temporary structure elements industry through the Business Model Canvas.

3. RESEARCH METHODOLOGY

Chapter 3 of this paper classified the 9 components for creating the Business Model (BM) Canvas into four parts: customers, products, financial aspects, and relationship. The components within each part were then collected through interviews, and data investigation as needed. The contents and sequence of creating the BM Canvas are outlined in Figure 2 and include the following steps: [1] Customer Understanding; [2] Product Composition; [3] Financial Aspects; [4] Relationship Aspects.

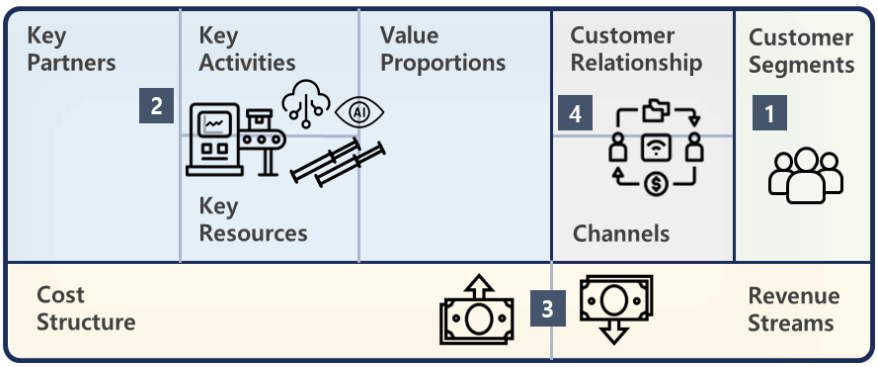

Figure 2. Sequence of Filling Business Model Canvas Out

Table 1 shows the subjects for whom interviews and data research were conducted for each part. In part [1], customers were interviewed about their pain points and technologies needed regarding their current situation. In part [2], products were composed that could be sold according to the required technology. And customers' opinions about the products were collected. In part [3], rental companies which are direct buyers of the business were interviewed about demand costs. When quantitative values about general business were needed, data was investigated through industrial reports, etc. Lastly in part [4], customers were interviewed about their opinions on the service provision structure.

Table 1. Rental Company Costs and Revenues

Part	Research Method	Subject			
		Rental Company	Contractor	Project Owner	Other Company
[1] Customer Understanding	Interview	O	O	O	X
[2] Product Composition	Interview	O	O	O	X
[3] Financial Aspects	Interview	O	X	X	O
	Investigation	O	X	X	O
[4] Relationship Aspects	Interview	O	O	O	X

3.1. Customer Understanding

The customers are categorized into rental companies directly managing the quality of temporary structure elements, contractors utilizing qualified temporary structure elements, and construction project owners who pay for the use of temporary structure elements. Interview were conducted with each customer group to assess (1) the status of temporary structure elements management and (2) improvement idea about the management of existing issues caused by temporary structure element.

3.1.1 Rental Company of Temporary Structure Elements

The results of interviews with two rental companies revealed that both companies have systematized their temporary structure elements management using document programs or in-house software. However, automation was not implemented in their systems. Additionally, there was a demand for cost reduction, particularly in labor, to enhance price competitiveness. It was also identified that on-site management for preventing incidents related to temporary structure elements is necessary. Furthermore, there was interest in improving worker convenience through an automated management system.

Table 2. Rental Companies Interviews

	Contents
As-is Status	• Management of the Quantity History of Temporary Structure Element • Specification-based management / Company's proprietary program-based • Systematized but not automated
To-be Need	• Cost reduction in management (Labor, etc., for price competitiveness) • Automated management system • Automatic check of KCs certification mark • Automatic check of quantity • Quality inspection and performance prediction

3.1.2 Contractor

After interviewing two contractors, both experienced delays in construction progress due to the low-quality of temporary structure element. This was because uncertified temporary structure elements was used, or low-quality products failed to pass quality tests. The quality issues with temporary structure elements concern the construction company's quality control manager and pose a direct risk to safety. However, in the case of on-site construction work, there is pressure related to the construction period, so there is a demand for ensuring the quality of temporary structure elements before they are brought to the site.

Table 3. Contractors Interviews

	Contents
As-is Status	• Construction progress is disrupted due to low quality of temporary structure element • Both the safety team and the quality team face risks about the element
To-be Need	• Securing the quality of temporary structure elements considering construction work efficiency • Demand for quality assurance before delivery to the field

3.1.3 Construction Project Owner

After interviewing a construction project owner, it was confirmed that there is a risk of damage to the company's image and cost loss in the event of a construction accident. Furthermore, the obligation to ensure safety has been increased with the strengthening of criminal penalties and fines under the significant industrial accident punishment law.

In the case of some ordering organizations, they had requested to ensure the quality test of every reused temporary structure element. However, in the case of large-scale construction projects, the quality test of all elements was not feasible due to the cost of many thousands dollars. Consequently, there is a demand from the owner for a comprehensive inspection of temporary structure elements and a demand for risk reduction related to low-quality and uncertified temporary structure element.

Table 4. Project Owner Interviews

	Contents
As-is Status	• A risk of damage to the company's image and the occurrence of cost losses in the event of an accident • An increase in the obligation to ensure safety, including criminal punishment and fines with the strengthening of penalties and fines under the significant industrial accident punishment law
To-be Need	• A demand for quality inspection and comprehensive inspection of all temporary structure elements • Elimination of risk of low quality and uncertified temporary structure element

3.2. Product Composition

Based on the in-depth interviews in Chapter 3.1, customer-specific pain points and methods to address these issues were derived. Subsequently, the products corresponding to the solutions were identified (Figure 3) among the research technologies under the 'Smart Safety for Temporary Structures' project mentioned in Chapters 1 and 2.

- For rental companies, it is possible to sell applications for automated quantity checks and certification mark checks to reduce operational costs, including labor expenses and to save working hours.
- For contractors, in case of inadequate quality test results leading to project delays, it is possible to purchase temporary structure elements that has been quality-managed to ensure sufficient strength according to reuse criteria beforehand.
- For construction project owner, in preparation for strengthened industrial safety regulations and the significant industrial accident punishment law, it is possible to secure a safety management system for temporary structure. Owner can pay the purchase cost for temporary structure elements with assured safety and quality management result reports to ensure compliance with safety measures and regulations.
- Rental companies can implement an automatic quality inspection system for temporary structure elements based on the demand from contractors and project owners. In this case, the automatic quality inspection system should involve sensing equipment and a cloud system.

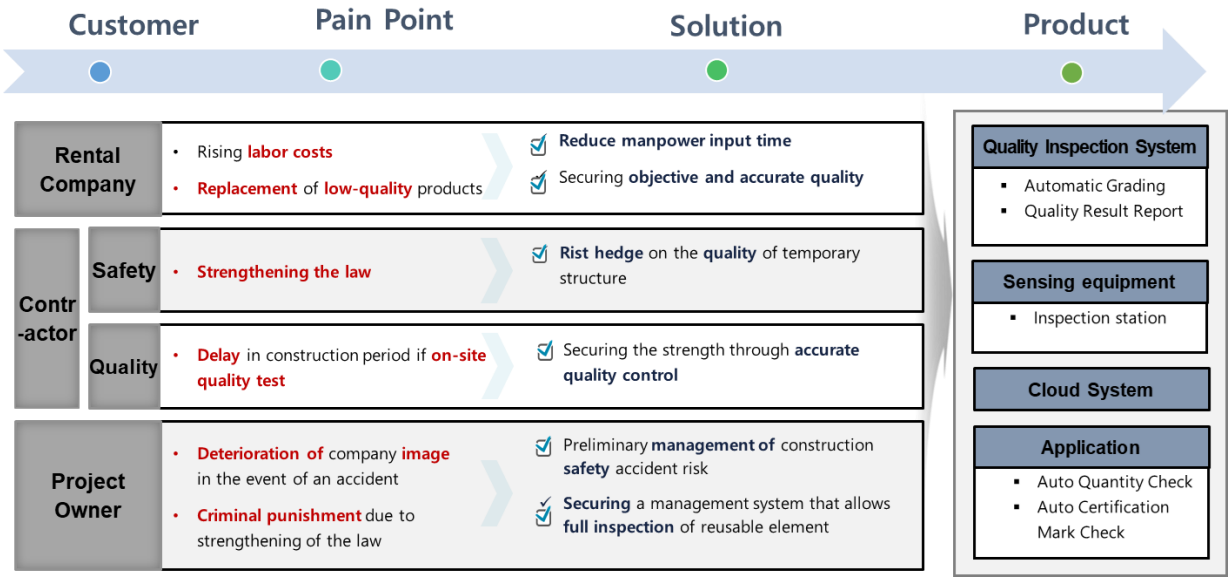

Figure 3. Product Composition to Address Customer-Specific Pain Points Derived from Interviews

3.3. Financial Aspect

In Chapter 3.3, the cost and revenue structure from the perspective of the operator and the direct customer, the rental company, were identified when selling the products composed.

3.3.1 Operator Perspective

From the operator's perspective, there are costs associated with establishing and maintaining the automatic quality inspection system, while revenue is generated from monthly rental fees. During the establishment phase, there are costs for purchasing sensing equipment. And during the maintenance phase, there are costs for hardware maintenance, including sensing equipment, and software maintenance for system upgrades.

Cloud rental fees are incurred continuously during both the establishment and maintenance phases. Hardware and software maintenance rates are based on reference data [17][18].

Table 5. Operator Costs and Revenues

	Category	Contents
(-) Introduction Cost	H/W purchase	Sensing equipment
	Cloud Rental	SaaS
(-) Maintenance Cost	H/W Maintenance	Acquisition value × Maintenance rate (approx.3 to 4.5 %)
	S/W Upgrade	S/W Costs × Maintenance rate (approx. 10%)
	Cloud Rental	SaaS
(+) Revenue	Monthly Rent	Labor cost for 2 people

3.3.2 Customer Perspective

For rental companies, which are direct users of the automatic quality inspection system, monthly rental fees are incurred as consumption costs, while cost savings in labor expenses through system usage represent benefit costs. Additionally, through interviews with a project owner, it has been confirmed that they have intention to increase rental fees about 6% more for temporary structure elements that managed with automated quality inspection system. This increase in rental fees is also expected to generate additional revenue for rental companies.

Table 6. Rental Company Costs and Revenues

	Category	Contents
(-) Cost	Monthly rent	Labor cost for 2 people
(+) Benefits	Save on Labor cost	Labor cost for 1 person
	Increase rent	Rent × Approx. 6%

3.4. Relationship Aspects

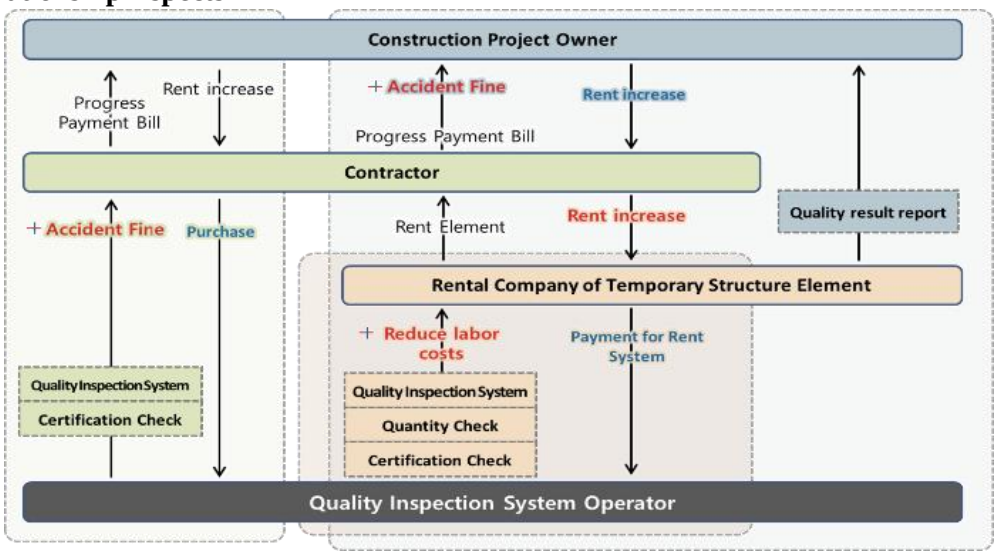

Figure 4. Stakeholder Service Delivery Structure

In Chapter 3.3, the cost and revenue structure of the operator and the customer were examined, and in Chapter 3.4, the service delivery structure with indirect customers, namely contractor and project owner, as well as business partners for system operation, was identified (Figure 4). The operator pays the cost for sensing equipment providers, software developers, and cloud service providers for their respective services. The operator then leases the comprehensive quality inspection system, including these services, to the rental company. Contractor rent quality-managed temporary structure elements through this system, and the rental fees are invoiced to the project owner. In this process, it appears that contractor and owner can reduce the cost of losses incurred due to industrial accidents

4. BUSINESS MODEL CANVAS

The completed business model canvas, formed by combining the analysed components from perspectives such as customers, products, finances, and management in Chapters 3.1 to 3.4, is depicted in Figure 5. 'Customer Understanding' includes direct and indirect customers such as rental companies, contractors, and project owners. 'Product Composition' consists of the technologies composing the automatic quality inspection system, the expected effects upon system implementation, and partner businesses. 'Financial aspects' are structured with items related to the operator's consumption costs and revenue. 'Relationship Aspects' encompasses a service delivery structure, including customer, product, and financial aspects.

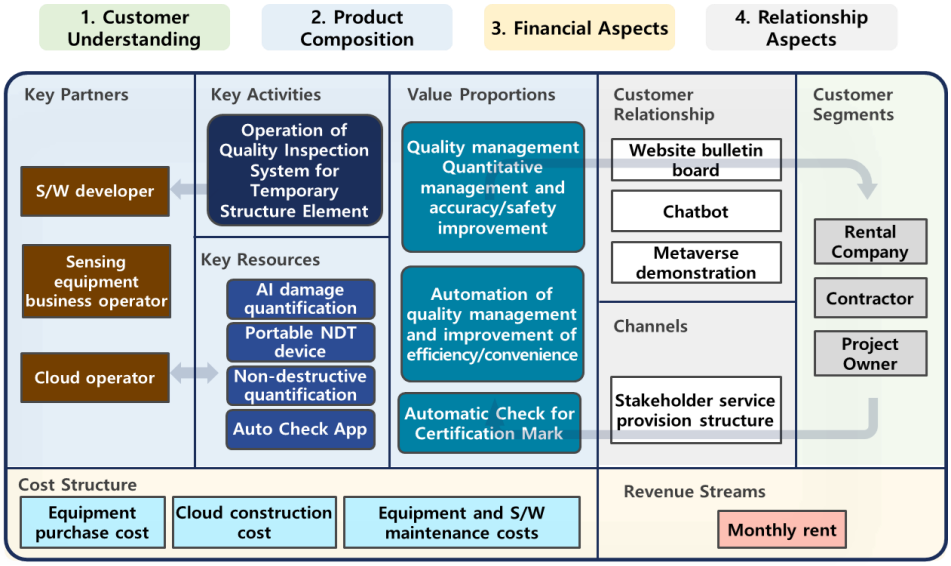

Figure 5. Temporary structure elements Business Model Canvas

5. CONCLUSION

Through this study, the following five points were confirmed:

1. To create a business model canvas for introducing an automatic quality inspection system for temporary structure elements, components were classified into four aspects: customer, product, financial, and management. The order of writing was also provided.
2. Through interviews, it's identified that the current issues and demands for technologies that can address the quality management of temporary structure elements from customers' perspective.
3. This research examined the cost and revenue components for both operators and customers when commercializing the automatic quality inspection system for temporary structure element.
4. After confirming the relationships between customers, products, and financial elements, the service delivery structure is constructed in respect of operation.
5. This research presented the business model canvas for introducing an automatic quality inspection system for temporary structure element.

The results of this study are expected to serve as a foundation for institutionalizing and expanding introducing quality management for experimental equipment utilizing smart technology in the future.

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