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Development of a Technology Assessment Model by Patents and Customers' Review Data

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Abstract**—**Recent years have seen an increasing number of patent disputes due to excessive competition in the global market and a reduced technology life-cycle; this has increased the risk of investment in technology development. While many global companies have started developing a methodology to identify promising technologies and assess for decisions, the existing methodology still has some limitations. Post hoc assessments of the new technology are not being performed, especially to determine whether the suggested technologies turned out to be promising. For example, in existing quantitative patent analysis, a patent's citation information has served as an important metric for quality assessment, but this analysis cannot be applied to recently registered patents because such information accumulates over time. Therefore, we propose a new technology assessment model that can replace citation information and positively affect technological development based on post hoc analysis of the patents for promising technologies. Additionally, we collect customer reviews on a target technology to extract keywords that show the customers' needs, and we determine how many keywords are covered in the new technology. Finally, we construct a portfolio (based on a technology assessment from patent information) and a customer-based marketability assessment (based on review data), and we use them to visualize the characteristics of the new technologies.

Keywords**—**Technology assessment, patents, citation information, opinion mining.

I. Introduction

ANALYZING a technology development and the resulting opportunities has become more necessary due to the risks inherent in launching and growing new businesses [1]. New technology can be the basis of new businesses, and the assessment of promising technology is an important factor for any successful business. In such analysis, patents, which contain various technological contents, are an effective resource. The patent analysis involves estimating the direction of technological research from complex technological documents [2]. To be specific, patent citation information is one of the most important parts of assessing a technology's effects and applicability. However, previous studies in this area have several limitations. First, since citation information is a factor that accumulates over time, these analytic methods are difficult to apply to recently published patents. Second, marketability assessments that are published before a new technology is commercialized tend to rely on expert opinions because customer inputs are not yet available. This not only requires a great time and financial costs but could also lead to inconsistent results due to different preferences and views among the experts. This paper, therefore, proposes a process that establishes indicators for assessing the promise of new technologies. To make such an assessment, we first collect the patent information for existing technologies; we then extract the features that significantly affected the development of promising technologies and use those features as indicators for technological assessment. By doing so, we can replace the citation factor and extract patent-specific features of promising technologies. Then, we extract major technological keywords from customer reviews, using the similarity between new technologies' patents descriptions and these keywords as an indicator of marketability. We also perform opinion mining, focusing on extracting and applying customers' opinions directly—thus reducing dependence on experts' opinions. Finally, we construct a portfolio based on two assessment indicators (technology and marketability) and visualize the characteristics of promising technologies.

The overall structure of this paper is as follows: Section II examines the existing studies on approaches for analyzing the promise of new technologies. Section III describes the research process for new technology assessment. We show a case study using the proposed research process in Section IV. Finally, in Section V, we describe the contributions and limitations of this research and suggest directions for future work.

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II. Literature Review

A. Technology Opportunity Analysis and Assessment

Technology opportunity is the ability to achieve technological advances in each industrial sector. Lately, there has been a dominant trend toward acquiring a promising technology opportunity and then assessing that technology in research and development; companies all over the world are now seeking to achieve better technological competitiveness through new technological development [3]. Technology opportunity analysis and assessment are effective means for businesses to achieve sustainable momentum by making profits in the medium to long term and finding possible technological advances [4]. Specifically, technology opportunity can contribute to the expansion of businesses' ranges. Broadly, it can be applied to policies for developing or managing a country's future technology. Technology opportunity analysis and assessment can be divided into two methods: qualitative analysis (based on experts' opinions) and quantitative analysis (based on data). Qualitative analysis, including the Delphi method, AHP (Analytic Hierarchy Process), and the scenario method, is based on the opinions of experts. In the early stages, technology opportunity analysis and assessment rely on expert

opinions to anticipate future technology when there is a high level of uncertainty [5]. While these expert opinions are still important, several studies have found that they are not always accurate, and the increasing availability of technological data has aroused controversy about these experts' credibility. This qualitative analysis requires great time and financial costs, but it could lead to inconsistent results due to the experts' differing preferences and views [6], [7]. Therefore, many studies have used analysis based on objective data from the bibliography or text of patents. Recently, these studies have focused on analyzing patents using text-mining or bibliography analysis, allowing for the systematic assessment of new technology. As such, many studies have recently explored technology opportunities and assessment through text mining of patent data or through bibliographic analyses.

B. Discovering Technology Opportunity and Assessment Using Patents

Patents are objective and standardized technological documents used to understand new technology. They have been widely used to analyze the level and quality of technology. Various approaches have been proposed for finding vacant technologies, such as 'outlier' analysis and applying patents' citation information. However, these approaches have some limitations [8]-[10]. The existing technological assessment models used in patent analytics are mostly based on citation information. Since citations accumulate over time, recent patents have a lack of citation data compared to those from the past. Therefore, this analytic method is difficult to apply to recently published patents. Marketability assessments of new technologies also tend to rely on the opinions of experts such as marketing managers and economists because data on customer inputs are not available. This not only requires a lot of time and money but can lead to inconsistent results due to experts' differing preferences and views.

III. Research Framework

A. Overall Research

In the process of new technology assessment, technology indicators and marketability indicators are assessed based on patent information and customer reviews, respectively, to assess promising technologies. First, we collect the patents of new (existing) technologies to extract assessment indicators and perform cluster analysis on the data. The outcome of this analysis, called 'outlier' analysis, is defined as a new technology. Then, we extract the attributes that can have significant effects on advances in those new technologies. These promising technologies are classified into three categories: high utility, high applicability, and high durability. The meaningful patent indicators for each type are used as indicators for technology assessment. Next, we collect customer review data on these technologies and use opinion mining to extract both positive and negative keywords. These extracted keywords are used to calculate a marketability score by measuring the correlation between customers' needs/claims and technology. In this study, we define higher correlations as implying that a target technology has a greater possibility of meeting customer demands and of improving assessments, and we visually present the characteristics of the assessment target.

B. Technology Assessment: Detecting Outliers

An outlier (a technology that is not classified into a specific group) is extracted from the collected patents. In this study, this vacant technology defined as a new technology [11]. We extract the patent indicators that advance the technology toward a promising future and use them as assessment indicators (as shown in Fig. 1). Bibliographic coupling is based on the idea that patents with a high percentage of common citations belong to similar technological domains (as shown in Fig. 2). Considering that citations are made through a semantic analysis by inventors and patent examiners, this process makes it easy to identify similarities between technologies and even assumes that analysis can be performed by non-experts with relatively little understanding of a specific technology. This paper measures the similarity between two patents as a cosine distance calculated from a bibliographic coupling matrix, and it grouped the technologies into domains. After the grouping process, the paper extracts outliers.

C. Technology Assessment: Development & Application of Technology Assessment Indicators

First, we collect two types of data from the previous patents of the assessment target: the first patent bibliography of a new technology (as shown in Table I) and the bibliography that has accumulated since the first patent (as shown in Table II). The accumulated bibliographies are indicators used to assess a promising technology's level of advancement from the vantage point of the present, and the first patent bibliographies are used as significant factors that affect a technology's advancement. These factors are used as assessment indicators for each promising technology.

The extracted outliers are compared with the three directions of technological advancement and with the technological characteristics at the time the outliers are found (Fig. 3). The promising technologies with high utility are divided into two groups based on the number of patent citations. Likewise, the technologies with high applicability are grouped based on the number of technological domains cited on a patent renewal before the patent expires. Based on these three groups (high utility, high applicability, high durability), we compare and extract the effective patent indicators.

D. Marketability Assessment

In this section, customer reviews of a target technology are collected for a marketability assessment. We perform opinion mining from the collected reviews and extracts both positive and negative keywords; the keywords related to satisfaction with the demanded features are marked as positive, and customer claims are marked as negative. Then, by collecting the patent data of the assessment target, we measure the accuracy of the positive and negative keywords. By doing so, we can perform a marketability assessment using this quantitative metric to show the coverage of the assessment

target in terms of customer satisfaction and claims.

Finally, we construct a portfolio based on two assessment indicators—technology and marketability—and visualize the characteristics of each promising new technology. The portfolio map lists the 10 technologies with the highest scores from each technology or marketability assessment.

IV. Case Study

A. Technology Assessment: Detecting Outliers

In this study, we first built the indicators for a technological assessment of new technology. We selected a technology of car door systems to understand how the technology attributes from the past affected the advancement of this promising technology, and we extracted the relevant indicators. A total of 576 patents published from January 1, 2000, to January 1, 2005, were collected from the United States Patent and Trademark Office (USPTO). To identify outliers among the 576 collected patents, we performed a bibliographic coupling analysis on the collected patents and connected all nodes that had cosine similarity of 0.5 or higher (Fig. 4). As a result, a total of 112 outlier patents were identified that did not belong to the predefined technological groups.

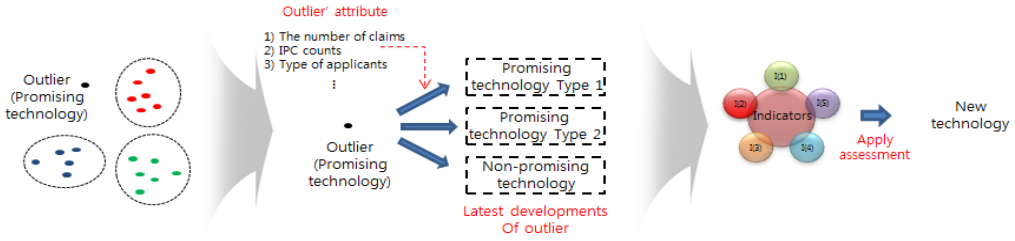


Fig 1. A process of extracting assessment indicators for technology

TABLE I
Patent Indicators at the Time of New Technologies Appearance

Patent Indicator	Operational definition	Indicator Description
Range of Patent Rights on technology	The number of claims	Possibility to develop promising technologies according to the range of patent rights on technology
Technological scope	The number of IPC	Possibility to develop promising technologies according to a number of technology categories a target technology belongs to
Human resources participated in the development of new technology	The number of applicants and inventors	Possibility to develop promising technologies by a number of participants in the development
Technological basement	The number of references	Possibility to develop promising technologies based on technological bases
Academic basement	The percentage of references not related to patents	Possibility to develop promising technologies based on academic bases
Characteristic of Tech-developing Organizations	Types of applicants (company, individual)	Direction of developing promising technologies based on the characteristics of developing organizations
Advancement of technology	The percentage of recent references	Possibility to develop promising technologies according to a percentage of recent patents in the references

TABLE II
Accumulated Features since the Appearance of New Technologies

Patent indicators	Operational Definition	Indicator Description
Technological utility	a number of citation	Promising technologies with high possibilities to be utilized in future researches
Technological applicability	a total number of IPC in cited patents	Promising technologies that can be applied to other technology groups
Technology durability	Whether patents are to be renewed	Promising technologies with high possibilities to use in the future

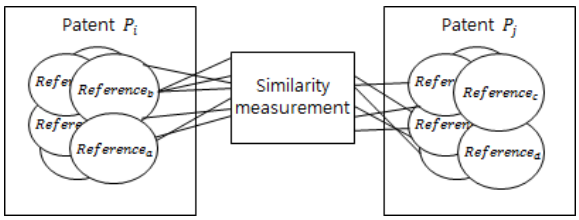
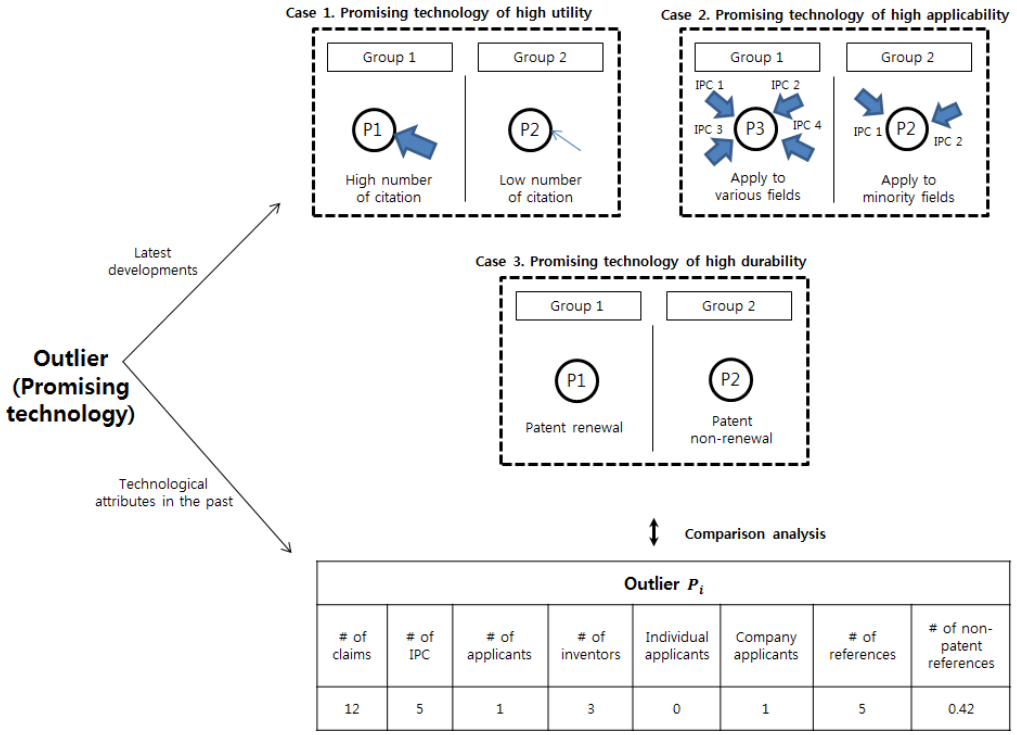


Fig. 2 Bibliographic coupling analysis



Outlier P_i							
# of claims	# of IPC	# of applicants	# of inventors	Individual applicants	Company applicants	# of references	# of non-patent references
12	5	1	3	0	1	5	0.42

Fig. 3 The comparison between each type of promising technology and its technical features at the time of technology appearance

B. Technology Assessment: Development and Application of Technology Assessment Indicator

For each promising technology, we analyzed the relationships between the patent indicators at the time of publication and followed its advancement. The promising technologies were classified into three categories: high utility, high applicability, and high durability. Since the collected data did not follow a normal distribution, a nonparametric test was used to perform a per-group analysis. The promising technologies with high utility are divided into two groups based on the medians of their citation counts. The results showed that effective patent indicators included the number of inventors and applicants, the number of references, the rate of non-patent references, and the rate of the recently published references (Table III).

More specifically, the patents with higher numbers of technological contributors (such as inventors and applicants) were more likely to have high utility. The technologies with strong technological foundations—which can be identified by the number of references, and more importantly, the number of non-patent references—also show a strong correlation with high utility; higher numbers of non-patent references imply stronger scientific backgrounds. To classify the technologies with high technological applicability, we grouped them into two subgroups based on the total number of IPCs (International Patent Classifications) for cited patents, and we then performed a nonparametric test. As a result, the number of IPCs serves as an effective indicator of high applicability, as summarized in Table IV. It turns out that a higher number of IPCs implies a higher level of technological applicability.

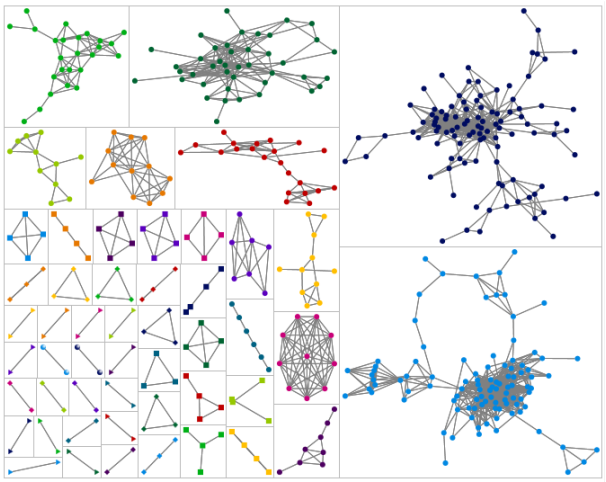


Fig. 4 Technology groups created by bibliographic coupling analysis

The third type, technologies with high durability, was identified using a nonparametric test between two groups based on the existence of renewal, as shown in Table V; a higher percentage of recent references implied a higher technological durability. The identified technological assessment indicators for each type of promising technology were then applied to 293 patents relating to car door systems published between 2013 and 2015 at the USPTO. A standardized score was calculated using the extracted technological assessment indicators. Since there are four indicators of high utility, we used the average of the standardized score for each indicator. The technological

assessment values for utility, applicability, and durability (after Max-Min standardization) are presented in Tables VI-VIII, respectively. The result of the technological durability assessment was not standardized because the indicator is the rate of recently published references. Likewise, the two indicators for utility (the rate of non-patent references and the rate of recently published references) were not standardized.

TABLE III
A NON-PARAMETRIC TEST ON PROMISING TECHNOLOGY ASSESSMENT WITH HIGH TECHNOLOGICAL UTILITY

Patent indicator	Mann-Whitne's U	Wilcoxon's W	Z	Significance probability
The number of claims	1,444	3,040	-0.723	0.470
The number of IPC	1,454	3,050	-0.674	0.500
The number of applicants and inventors	1,238	2,834	-2.101	**0.036****
Individual applicants	1,540	3,136	-0.316	0.752
Company applicants	1,540	3,136	-0.316	0.752
The number of references	1,256.5	2,852	-1.817	**0.069***
The percentage of references not related to patents	1,399.5	2,995	-1.826	**0.068***
The percentage of recent references	1,242.5	2,995.5	-2.018	**0.044****

**: Significance probability 0.05
*: Significance probability 0.1

TABLE IV
A NON-PARAMETRIC TEST ON PROMISING TECHNOLOGY ASSESSMENT WITH HIGH TECHNOLOGICAL APPLICABILITY

Patent indicator	Mann-Whitne's U	Wilcoxon's W	Z	Significance probability
The number of claims	1543	3139	-0.146	0.884
The number of IPC	906	2502	-3.917	**0.000****
The number of applicants and inventors	1464.5	3060.5	-0.659	0.510
Individual applicants	1428	3024	-1.580	0.114
Company applicants	1428	3024	-1.580	0.114
The number of references	1298	2894	-1.575	0.115
The percentage of references not related to patents	1564	3160	-0.043	0.965
The percentage of recent references	1462.5	3058.5	-0.654	0.513

**: Significance probability 0.05
*: Significance probability 0.1

TABLE V
A NON-PARAMETRIC TEST ON PROMISING TECHNOLOGY ASSESSMENT WITH HIGH TECHNOLOGICAL DURABILITY

Patent indicator	Mann-Whitne's U	Wilcoxon's W	Z	Significance probability
The number of claims	119.5	6,114.5	-0.794	0.427
The number of IPC	112	118	-0.944	0.345
The number of applicants and inventors	84	90	-1.567	0.117
Individual applicants	6,142	6142	-0.577	0.564
Company applicants	153	153	-0.577	0.564
The number of references	6,116.5	6116.5	-0.759	0.448
The percentage of references not related to patents	151.5	151.5	-0.546	0.546
The percentage of recent references	64	6059	-1.910	**0.056***

**: Significance probability 0.05
*: Significance probability 0.1

TABLE VI
TECHNOLOGICAL UTILITY ASSESSMENT OF RECENTLY PUBLISHED PATENTS ON VEHICLE DOOR SYSTEM

Rank	Patent number	Patent name	Utility score (standardization)
1	P107	Motor vehicle having a mechanism for moving a panel or door	0.3115
2	P201	Door mirror device for a vehicle	0.3107
3	P187	Switch engagement assembly for an automobile door panel	0.3065
4	P79	Door assembly for a vehicle	0.3004
5	P125	Door lock control apparatus for vehicle	0.2953
6	P276	Vehicle door latch system	0.2658
7	P189	Cable guide on a vehicle door	0.2613
8	P88	Method for controlling power to a motor in a vehicle door mirror	0.2607
9	P48	Cable feed device on a vehicle door, or flat cable connection	0.2584
10	P248	Adjustable striker for vehicle door latch	0.2582

Among 73 new technologies, P19 (a method for manufacturing a motor vehicle door hinge) and P225 (a vehicle door hinge) scored among the top 10 in both technological applicability and technological durability. In addition, P79 (a door assembly for a vehicle) scored in the top 10 in applicability and durability.

C. Marketability Assessment

We also performed a marketability assessment to analyze the new technologies. We collected customer reviews from 5 top automobile community sites (such as cars.com and autobytel.com) for the years 2008 through 2015 using a crawling package provided by the R programming language. The total number of opinions found was 21,521, and 1,413 of these were related to doors. For the customer opinions related to doors, we performed a sentiment analysis to identify whether

a given customer opinion was positive or negative, and we analyzed the results using the Semantria, semantic analysis tool. Semantic analysis is a kind of opinion mining that is designed to analyze the opinions, attitudes, and emotions people express toward a certain topic, person, or issue. It can measure the intensity of opinions' positivity/negativity by extracting subjective phrases on a given topic. In this study, the positive and negative keywords from the customer review data were extracted (as shown in Table IX). The keywords used more than 100 times were analyzed, and after filtering out the stop words, the total number of extracted keywords was 33.

TABLE VII
TECHNOLOGICAL APPLICABILITY ASSESSMENT OF RECENTLY PUBLISHED PATENTS ON VEHICLE DOOR SYSTEMS

Rank	Patent number	Patent name	Applicability score (standardization)
1	P164	Method for the installation of an apparatus for spring-assisted swinging of a liftgate or door in a vehicle	1.0000
2	P19	Method for manufacturing motor vehicle door hinge	0.6667
	P21	Door inner panel for automobile and method of manufacturing same	0.6667
	P27	Lighting system arranged in vehicle door	0.5000
	P59	Vehicle door lock	0.5000
4	P150	Circuit for selectively producing switching signals, especially for a vehicle door locking, a vehicle, system, and method equipped therewith for protecting areas of risk as well as a system, system components and method for hermetically transferring validatable data	0.5000
	P234	Clutch, motor and vehicle door opening/closing device	0.5000
	P225	Vehicle door hinge	0.3333
8	P259	Temperature control apparatus for heating a side door of a vehicle	0.3333
	P252	Door handle apparatus for vehicle	0.3333

Among these, keywords such as 'break,' 'mirror,' and 'noise' were classified as negative (implying customer complaints), and all other keywords were classified as positive. As the frequency of keywords with a higher sentiment value, such as 'comfort,' 'interior,' and 'smooth,' increases, the target technology is considered to have higher customer satisfaction. Similarly, it can be interpreted that patents with more negative keywords indicate an assessment target that is meant to alleviate customer complaints.

TABLE VIII
TECHNOLOGICAL DURABILITY ASSESSMENT OF RECENTLY PUBLISHED PATENTS ON VEHICLE DOOR SYSTEMS

Rank	Patent number	Patent name	Durability score (standardization)
1	P5	Vehicle trunk door structure	0.1818
2	P8	Door weather strip for motor vehicle	0.1428
3	P116	Backdoor for automobile	0.1111
4	P161	Vehicle door opening warning system	0.0909
5	P90	Outside handle device for vehicle door	0.0769
6	P79	Door assembly for a vehicle	0.0769
7	P225	Vehicle door hinge	0.0400
8	P19	Method for manufacturing motor vehicle door hinge	0.0370
9	P16	Replacement door handle for vehicle	0.0250

TABLE IX
SENTIMENT ANALYSIS RESULTS OF CUSTOMER REVIEW DATA

Type	Keyword	Sentiment value
Positive Keywords Indicating Customer Satisfaction	accelerate	0.0411
	bluetooth	0.2532
	camera	0.2019
	comfort	0.4444
	control	0.1744
	design	0.2658
	engine	0.1473
	exterior	0.2969
	fit	0.2660
	highway	0.1406
	interior	0.3311
	light	0.0334
	lock	0.0083
	mileage	0.2955
	mpg	0.1891
	passenger	0.0660
	power	0.2734
	radio	0.1643
	seat	0.1379
	shift	0.0806
	size	0.3407
	smooth	0.3604
	snow	0.2135
	sound	0.2883
	space	0.2825
	speed	0.2042
	stereo	0.3345
	style	0.3150
	trunk	0.1954
	wheel	0.1960
Negative Keywords Indicating Customer Dissatisfaction	brake	-0.0217
	mirror	-0.0535
	noise	-0.0475

The frequency of keywords is measured in binary form per patent based on their appearance. Then, for each patent, the sum of the frequency of the 33 keywords is standardized and used to calculate a marketability score. The top 10 patents, as sorted by standardized marketability scores, are summarized in Table X.

The assessment scores for technology and marketability are shown in Table XI. To visually present the scores, a portfolio map is constructed using the scores as the two axes. A technology assessment score is mapped, taking an average of three indicators (Fig. 5).

TABLE X
MARKETABILITY ASSESSMENT OF RECENTLY PUBLISHED VEHICLE DOOR SYSTEM PATENTS

Rank	Patent number	Patent name	Marketability score
1	P150	Circuit for selectively producing switching signals, especially for a vehicle door locking, a vehicle, system, and method equipped therewith for protecting areas of risk as well as a system, system components and method for hermetically transferring validatable data	1.00
2	P107	Motor vehicle having a mechanism for moving a panel or door	0.50
3	P27	Lighting system arranged in vehicle door	0.50
4	P122	Door attached to cabin for work vehicle	0.45
5	P141	Damping stop for hinge, especially for vehicle door hinge	0.40
6	P16	Replacement door handle for vehicle	0.40
7	P259	Temperature control apparatus for heating a side door of a vehicle	0.40
8	P261	Automated vehicle cargo door opener	0.40
9	P91	Door module for installation in a motor vehicle door	0.40
10	P145	Vehicle audio system having door mounted speaker support	0.35

TABLE XI
ASSESSMENT SCORES FOR TECHNOLOGY AND MARKETABILITY AND TOP 10 OF PATENTS

Top 10 of technology assessment				Top 10 of Marketability assessment			
Rank	Patent	Score of tech.	Score of marketability	Rank	Patent	Score of tech.	Score of marketability
1	P164	0.4027	0.2000	1	P150	1.0000	0.2020
2	P19	0.3049	0.3000	2	P107	0.5000	0.1038
3	P21	0.2235	0.0500		P27	0.5000	0.2084
4	P27	0.2084	0.5000	4	P122	0.4500	0.0314
5	P59	0.2075	0.3500		P141	0.4000	0.0763
6	P150	0.2020	1.0000		P16	0.4000	0.1162
7	P8	0.1969	0.1000	5	P259	0.4000	0.1612
8	P234	0.1929	0.3500		P261	0.4000	0.0502
9	P225	0.1912	0.0500		P91	0.4000	0.0763
10	P259	0.1612	0.4000	10	P145	0.3500	0.0117

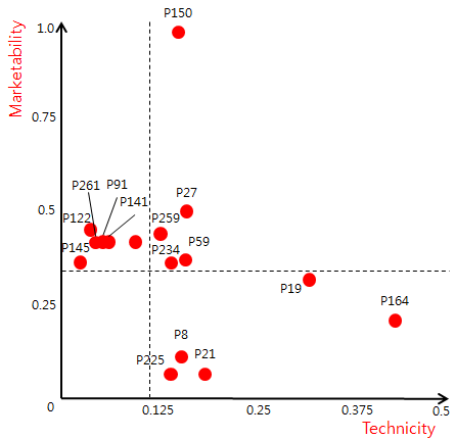


Fig. 5 Portfolio map for assessment

These five patents are among the top 10 according to for both technology and marketability: P27 (a lighting system for a vehicle door), P150 (a circuit for selectively producing switching signals, especially for a vehicle door lock, a method for protecting areas of risk in a system, and a method for hermetically transferring data that can be validated), P259 (a temperature control apparatus for heating the side door of a vehicle), P234 (a clutch motor and vehicle door opening/closing device), and P59 (a vehicle door lock). P27 is s technology that turns on in-car lights when opening and closing doors, and P150 is a door-lock system that protects a driver inside the car. P259 is a heating device for use in car door panels. P234 is the technology used to smooth the connection of moving transmission parts inside car door panels. Lastly, P59 is locking technology that allows multiple locations of vehicle door locks.

V. Conclusion

Many studies have been conducted about how to create technological opportunities and assess new technologies, especially by utilizing patent information. This study provided assessment indicators, which can replace the citation information that interrupts the process of patent application, in addition to an assessment model that allows for the direct reflection of customers' feedback and that assesses the prominence of new technologies.

Although the proposed method improves upon the systematic technological assessment model, some limitations yet remain. First, since this study examined only three types among the tremendously varied types of promising technologies, further studies are needed to assess the other types and to take a multidimensional approach to analyzing them based on innovative analysis methods.

Acknowledgement

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