Strategic Analysis of Digital Technologies in the Healthcare Sector through the Application of Multiple Preference Relations Combined SWOT Analysis

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Abstract

Digital technologies are including many different technologies that enable information to be collected, stored, and easily accessed when needed. The use of digital technologies is also increasing in the health sector, where service processes are intense and complex. Strategic considerations would be appropriate to analyze the use of these technologies. For this reason, in this study, a strategic evaluation was made on digital technologies in the health sector. With the SWOT analysis, the current situation analysis regarding digital technologies in the health sector was made. Then, the weights of SWOT factors were determined with the multiple preference relations (MPR) integrated DEMATEL method. Subsequently, alternative strategies were determined and prioritized with MPR integrated TOPSIS method. The MPR technique is aimed to analyze the uncertainties and reach more accurate and reliable results by gathering the evaluations of experts in different formats or incomplete opinions under a single group decision. The proposed methodology integrated with SWOT analysis on digital technologies in the health sector constitutes the originality of the study. In line with the results obtained from this study, both researchers and managers will be able to create and use more effective digital technology strategies for the health sector.

Keywords
SWOT analysis, Multiple Preference Relations, DEMATEL, TOPSIS, Healthcare, Digital Technologies.

1. Introduction
Digital technologies are a broad term that includes many different technologies such as information technologies (IT), mobile and sensor-based technologies, internet of things, artificial intelligence applications, which enable information to be collected, stored and easily accessed when necessary. The benefits of digital technologies to businesses today are so important that they cannot be ignored. As in every business, the use of digital technologies is increasing in the health sector, where service processes are intense and complex (Bayeshova and Omarov, 2019).

While the health sector improves in diagnosis, treatment and post-treatment processes with the effect of digitalization, it also offers solutions to patients and their relatives at many points such as online appointments and easy access to the right information in the field of health. In this context, the use of digital technologies in the health sector will provide safer and higher quality services, while reducing costs and increasing efficiency and quality of care. To achieve these goals, health systems must be constantly monitored and evaluated. In this study, a strategic evaluation was made on the use of digital technologies in the health sector. SWOT analysis, which enables the determination of the strengths, weaknesses, opportunities and threats of the enterprises, was made and alternative strategies were determined by analyzing the current situation regarding digital technologies in the health sector.

Evaluation of these factors and strategies includes a group decision making (GDM) approach with multiple expert opinions. When considering the GDM approach, the perspectives of the decision makers may differ from each other and may want to evaluate them in different formats. Multiple preference relations (MPR) techniques are often applied to deal with different forms of evaluation (Buyukozkan and Ilicak, 2019). SWOT factors were evaluated using the MPR integrated DEMATEL (MPR-DEMATEL) method, then the most important strategy was determined by weighting the strategies with the MPR integrated TOPSIS (MPR-TOPSIS) method.

1.1 Objectives
This study aims to propose an integrated SWOT analysis with MPR integrated DEMATEL and TOPSIS method, to show the application of the proposed methodology, and to analyze the alternative strategies of digital technologies in the health sector. The originality of the study is the proposed methodology. Decision makers (DMs) who have different backgrounds or ideas can state their preferences in different formats. MPR technique is used with DEMATEL and TOPSIS techniques to combine different assessments of SWOT factors and alternative strategies. The integrated methodology with a GDM perspective is proposed in the field of strategic analysis of digital technologies in the health sector for the first time in the literature. With this study, the most appropriate strategies can be obtained in digitalization process of health sector.

2. Literature Review
2.1 SWOT Analysis
Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is a commonly used method for companies and provides them to examine their internal strengths and internal weaknesses of a product or service and defines the opportunities and threats of the external environment (Kahraman et al., 2007).

In the literature, MCDM methods are used to evaluate SWOT analysis quantitatively to address this weakness. Similarly, Kurttila et al. (2000) used the Analytical Hierarchy Process (AHP) with SWOT analysis to quantitatively evaluate the strategic significance of certification of the forest region. Di Lallo et al. (2016) used SWOT analysis with Analytical Network Process (ANP) in the field of forest certification. Some studies have proposed SWOT analysis with fuzzy methodologies, such as Li et al. (2020), Büyüközkan et al. (2021), Havle et al. (2021), Efe et al. (2022), Akcaba and Eminer (2022). However, in the field of healthcare digital technologies strategy evaluation a study that combines SWOT analysis and DEMATEL, TOPSIS with MPR technique has so far been absent from the literature.

2.2 Multiple Preference Relations (MPR)
MPR technique is commonly utilized in decision-making processes and with this approach, DMs with different backgrounds/perspectives can present their choices in a variety of ways. At the same time, this method can deal with expert evaluations that are lacking/incomplete knowledge of the subject (Buyukozkan and Tufekci, 2021).
When we examine the literature, there are many studies that combine MPR in different areas with different methods. In this section, some studies with MPR are given in Table 1. Based on the literature review, it was seen that MPR has not been integrated with DEMATEL and TOPSIS and in the field of healthcare digital technologies strategy evaluation.

Table 1. Some studies with MPR.

References	Integrated Method	Area	Type
Zhang et al. (2004)	-	Student Information Project assessment	Illustrative
Büyüközkan and Feyzioğlu (2005)	Fuzzy GDM, QFD	Software development	Illustrative
Choudhury et al. (2006)	-	Technology selection	Illustrative
Büyüközkan et al. (2007)	Fuzzy GDM, QFD	Hatch door development of a car	Illustrative
Gao and Peng (2011)	SWOT analysis	-	Illustrative
Büyüközkan and Çifçi (2012)	QFD	Turkish software company	Case Study
Jiang and Xu (2014)	-	-	Illustrative
Büyüközkan and Çifçi (2015)	Fuzzy GDM, QFD	Portable entertainment and game systems design	Case Study
Peng et al. (2015)	SWOT analysis	Shareholders of a forest holding	Illustrative
Büyüközkan and Güleryüz (2015)	Fuzzy GDM, QFD	Turkish software company	Case Study
Yao et al. (2020)	GDM, Interval type-2 fuzzy preference relations	Wastewater treatment technologies	Case Study
Wen et al. (2020)	2-tuple linguistic representation, VIKOR	Supplier selection	Illustrative
Ma et al. (2020)	GDM, Uncertainty theory	-	Illustrative
Frej et al. (2021)	Benefit-to-cost ratio model	Portfolio selection	Case Study
Wang et al. (2021)	Mathematical programming model	Student selection	Illustrative

3. Methods

In this study, digital technologies strategic evaluation in healthcare sector is made. For this, SWOT analysis was created. By using an integrated MPR-DEMATEL methodology, SWOT factors are evaluated. After that, strategies are determined and by utilizing MPR-TOPSIS methodology, alternative strategies are ranked. This section describes the proposed methodology step by step.

Step 1- Creating the SWOT: SWOT factors are described by benefiting from expert views and literature research.

Step 2–Establishing the group direct relationship matrix: A direct relationship matrix is created by using MPR technique to harmonize diverse preferences of DMs.

Step 2.1 – Consolidating different individual evaluations:

DMs may provide an importance degree vector (u1,… ,uN) where ui$\in$ [0,1] i = 1,…,N. If ui is closer to 1, then it means that it is more important than others.

$$z_{ij} = u_i/u_j \text{ for all } 1 \leq i \neq j \leq N \tag{1}$$

DMs may offer an ordered vector (o(1), …, o(N)). In this, vector o(i) represents the importance ranking of criteria i. If i is the most critical factor, then O(i)=1 and if least significant, then O(i)=N.

$$z_{ij} = 9ui-uj \quad \text{for all } 1 \leq i \neq j \leq N$$

where (2)

$$u_i = (N - o(i))/(N - 1)$$

DMs may present a linguistic importance vector ($s_1, \ldots, s_N$) where s_i, i = 1, …, N. Given a fuzzy triangular number can be noted as (a_i, b_i, c_i) where b_i is the most common value. The membership functions of linguistic terms for fuzzy triangular quantification are as follows: Not Important (NI)= (0.00, 0.00, 0.25), Some Important (SI) = (0.00, 0.25, 0.50), Moderately Important (MI) = (0.25, 0.50, 0.75), Important (I) = (0.50, 0.75, 1.00) and Very Important (VI) = (0.75, 1.00, 1.00).

$$z_{ij} = 9bi-bj \quad \text{for all } 1 \leq i \neq j \leq N \tag{3}$$

DMs may present an uncertain matrix, where some values are deficient. Benefiting from Table 2, the importance degrees of criteria, fuzzy linguistic variables $\tilde{p}_{ij} = (p^l_{ij}, p^m_{ij}, p^u_{ij})$ are found.

Table 2. Corresponding linguistic terms for evaluation.

Linguistic terms	**Fuzzy scales**
None (N)	(0, 0, 1)
Very low (VL)	(0, 0.1, 0.2)
Low (L)	(0.1, 0.2, 0.3)
Fairly low (FL)	(0.2, 0.3, 0.4)
More or less low (ML)	(0.3, 0.4, 0.5)
Medium (M)	(0.4, 0.5, 0.6)
More or less good (MG)	(0.5, 0.6, 0.7)
Fairly good (FG)	(0.6, 0.7, 0.8)
Good (G)	(0.7, 0.8, 0.9)
Very good (VG)	(0.8, 0.9, 1)
Excellent (E)	(0.9, 1, 1)

After the DMs constructed the missing comparison matrices, the defuzzification of evaluated preferences are calculated by using the formula below:

$$F(\tilde{p}_{ij}) = \frac{1}{2}\int_0^1 (\inf_{x \epsilon \Re} \tilde{p}^a_{ij} + \sup_{x \epsilon \Re} \tilde{p}^a_{ij})\, da \tag{4}$$

Then, missing values in a DMs evaluation can be calculated. Given a mutual preference relationship, the preference value $p_{ij}(i \neq j)$ can be computed in three ways with Eq. (5)-(7):

From $p_{ij} = p_{iy} + p_{yj} - 0.5$, we acquire the prediction, $cp^{y1}_{ij} = p_{iy} + p_{yj} - 0.5$ (5)

From $p_{yj} = p_{yi} + p_{ij} - 0.5$, we acquire the prediction, $cp^{y2}_{ij} = p_{yj} - p_{yi} + 0.5$ (6)

From $p_{iy} = p_{ij} + p_{jy} - 0.5$, we acquire the prediction, $cp^{y3}_{ij} = p_{iy} - p_{jy} + 0.5$ (7)

It is assumed that the priority value of one factor over itself is always equal to 0.5.

Estimating the consistency level of each preference relation: For calculating the consistency level, the following equations can be used:

$$H^1_{ij} = \{y \neq i, j \mid (i, y), (y, j) \in EV\} \tag{8}$$

$$H^2_{ij} = \{y \neq i, j \mid (y, i), (y, j) \in EV\} \tag{9}$$

$$H^3_{ij} = \{y \neq i, j \mid (i, y), (j, y) \in EV\} \tag{10}$$

In equations (8)-(10), H^1_{ij} , H^2_{ij} and H^3_{ij} are described, which are the sets of moderate alternatives a_y ($y \neq i, j$) which enables to evaluate the priority value $p_{ij}(i \neq j)$, and EV represents the set of factors being assessed by the DMs. The consistency level CL_{ij} is interrelated with priority value p_{ij} $(i \neq j) \epsilon$ EV, as shown below.

$$CL_{ij} = (1 - a_{ij}).(1 - \mathcal{E}p_{ij}) + a_{ij}.\frac{CP_i + CP_j}{2} \tag{11}$$
$$aij \in [0,1]$$

CL_{ij} described as a linear compound of the average of wholeness values related with two alternatives included in that preference degree CP_i and CP_j. In the Eq. (12), #EV represents the number of the priority values which are provided by the members.

$$CP_i = \frac{\#\,(EV)}{2(n-1)} \tag{12}$$

The related error εp_{ij} is computed as:

$$\varepsilon p_{ij} = \frac{2}{3}.\frac{\mathcal{E}p^1{}_{ij} + \mathcal{E}p^2{}_{ij} + \mathcal{E}p^3{}_{ij}}{K} \quad \text{where} \tag{13}$$

$$\varepsilon P_{ij}^1 = \begin{cases} \dfrac{\sum_{j \in H_{ij}^h} \left| cp_{ij}^{kh} - p_{ij} \right|}{\#\left(H_{ij}^h\right)} & , \text{if}\left(\#\left(H_{ij}^h\right) \neq 0\right); h \in \{1,2,3\} \\ 0 \ , \text{otherwise} & \end{cases} \tag{14}$$

$$K = \begin{cases} 3, \text{if } \left(\#\left(H_{ij}^1\right) \neq 0\right) \wedge \left(\#\left(H_{ij}^2\right) \neq 0\right) \wedge \left(\#\left(H_{ij}^3\right) \neq 0\right) \\ 2, \text{if } \left(\#\left(H_{ij}^a\right) \neq 0\right) \wedge \left(\#\left(H_{ij}^b\right) \neq 0\right) \wedge \left(\#\left(H_{ij}^c\right) \neq 0\right); \ a, b, c \in \{1,2,3\} \\ 1, \ \text{otherwise} \end{cases} \tag{15}$$

In the evaluation of consistency level, α_{ij}, a parameter to audit the impact of wholeness, can be computed as in the Eq. (16):

$$\alpha_{ij} = 1 - \frac{\#(EV_i) + \#(EV_j) - \#(EV_i \cap EV_j)}{4(n-1) - 2} \tag{16}$$

If CL_{ij} is not less than 0.5, then p_{ij} is consistent. DMs should revise their preferences if p_{ij} is not coherent and $\varepsilon p_{ij} \neq 0$. In the cases where p_{ij} is not cohesive and $\varepsilon p_{ij} = 0$, more known preference values are needed.

Step 2.2 - Gathering the assessments: All assessments are collected to describe a common opinion group. The ordered weighted geometric (OWG) operator is defined as:

$$\phi^G \{(\overline{w}^{k1}, p_{ij}^{k1}), \ldots .(\overline{w}^{kL}{}_k, p_{ij}^{kL_k})\} = \prod_{l=1}^{L_k} \left(p_{ij}^{k[l]}\right) \tag{17}$$

Here, $\{1, \ldots, L_k\} \rightarrow \{1, \ldots, L_k\}$ is a permutation such that $\overline{w}^{kl} \geq \overline{w}^{k[l+1]}$, $l = \{1, \ldots, L_k\text{-}1\}$, so $\overline{w}^{kl}$ is the lth largest value in the set $(\overline{w}^{k1}, \ldots, \overline{w}^{kL}{}_k)$. Comparative quantifiers such as "most", is represented as subsets of the interval [0,1]. Then for any $t \in [0,1]$, Q(t) indicates the degree to which the proportion t is compatible with the meaning of the quantifier it represents. For a non-decreasing relative quantifier, Q, the weights can be obtained as:

$$W_k = Q(k/K) - (Q(k-1)/K), \ k = 1, \ldots, K \tag{18}$$

where Q(t) is described as:

$$Q(t) = \begin{cases} 0, & \text{if } t < s \\ \frac{t-s}{v-s}, & \text{if } s \leq t \leq v \\ 1, & \text{if } t \geq v \end{cases} \tag{19}$$

If we show an example for relative quantitative determinants; "most" (0.3, 0.8), "at least half" (0, 0.5) and "as many as possible" (0.5, 1). The fuzzy quantifier Q is represented by ϕ_Q^G. For this reason, the whole multiplicative relative importance is acquired, as shown below:

$$p_{ij}^k = \Phi_Q^G\left(p_{ij}^{k1}, p_{ij}^{k2}, \ldots, p_{ij}^{kL_k}\right), \ 1 \leq i \neq j \leq N \tag{20}$$

Step 2.3 – Calculating the values for direct relationship matrix: The group opinion obtained from the P^k matrix which is obtained by Eq.(20), must be used to define the importance weights of criteria. Then, the importance of one factor compared to others in a fuzzy majority sense will be calculated. With using the OWG operator, Φ_Q^G, defined as follows.

$$\mathrm{QGID}_i^k = 1/2\left(1 + \log_9 \phi_Q^G\,(p_{ij}^k\colon j = 1,2,\ldots,N)\right) \tag{21}$$

for i = 1,2,…., N.

The degrees of importance for the group k in percentages are given below, after that normalization:

$$\mathrm{QGID}_i^k = \mathrm{QGID}_i^k / \sum_i \mathrm{QGID}_i^k \tag{22}$$

Step 3- Determining the normalized direct relationship matrix: Normalized direct relationship matrix (M) is obtained by using the smallest value (k) in the row and column. The main diagonal values of this matrix are 0.

$$M = k \times A \tag{23}$$

$$k = \min\left(\frac{1}{\max_{1\le i\le n} \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max_{1\le j\le n} \sum_{i=1}^{n} |a_{ij}|}\right) \quad i,j \in \{1,2,3,\ldots,n\} \tag{24}$$

Step 4- Obtaining the total relationship matrix: After obtaining the normalized direct relationship matrix, the total relationship matrix (S) is obtained with the help of the Eq.(25). This equation is represented by the unit matrix (I).

$$S = M + M2 + M3 + \ldots = \sum_{i=1}^{\infty\leftarrow} M^i$$
$$= M\,(I - M)\text{-}1 \tag{25}$$

Step 5- Calculation of dispatcher and receiver group: Dispatcher and receiver groups are calculated with the help of Eq.(26)-(28). The sum of the columns in the S matrix (R) represents the sum of the rows in the S matrix (D). By calculating the D and R equations and using the D-R and D+R values, the effect of each criterion on the others and the level of relationship with the others are determined. It shows that criteria with positive values in D-R have a higher effect on other criteria. Such criteria are called dispatchers. The criteria with a negative value for the D-R value are more affected by the other criteria. These criteria are called recipients. On the other hand, D+R values show the relationship between any criterion and other criteria.

$$S = \left[S_{ij}\right]_{nxn} \quad i,j \in \{1,2,3,\ldots,n\} \tag{26}$$

$$D = \sum_{j=1}^{n} S_{ij} \tag{27}$$

$$R = \sum_{i=1}^{n} S_{ij} \tag{28}$$

By making use of D+R and D-R, an effect-direction graph diagram can be obtained. With the help of a threshold value determined by the decision makers, some elements with a larger effect value than the threshold value are selected in the S matrix and an effect graph diagram is obtained. Points are displayed on a coordinate plane pointing to the horizontal axis D+R, the vertical axis D-R.

Step 6- Calculating the weights: Finally, with the help of the D+R and D-R values found, the weights are calculated by using the Eq.(29)-(30).

$$w_i = \{(D_i + R_i)^2 + (D_i - R_i)^2\}^{1/2} \tag{29}$$

$$W_i = \frac{w_1}{\sum_{i=1}^{n} w_i} \tag{30}$$

Step 7- Determining the strategies: After determining the SWOT factors, alternative strategies are identified with the guidance of the experts' opinions.

Step 8 – Creating the decision matrix: In this step, alternatives are compared to each other based on the factors, and prioritized according to their individual weights of influence. Here, DMs are expected to provide linguistic importance vectors to evaluate each alternative. After that, TOPSIS method steps are applied, and alternatives are ranked.

4. Data Collection and Processing

In this section, an application is given in order to analyze the usage of digital technologies in the healthcare sector and to develop strategies. In this application, first SWOT analysis is proposed. Second, MPR integrated DEMATEL methodology is used to determine the importance weights of the SWOT factors. After that, alternative strategies are developed, and the best strategy is selected through the MPR integrated TOPSIS methodology. The SWOT analysis is given in Table 3 which is created with the help of the experts and literature review (Bayeshova and Omarov, 2019), (Sharma and Sehrawat, 2020), (Rahati et al., 2016), (Altan, 2017), (Econsultancy, 2019).

Table 3. SWOT analysis for the usage of digital technologies in healthcare sector

Strengths:	**Opportunities:**
S1: Time savings, real-time monitoring and data processing, predictive modeling, with increased speed in service delivery	O1: Better organized and user-friendly interfaces
S2: Timely and fast access to necessary information, easy analysis/reporting and interpretation with the help of technology	O2: Making more work possible with less staff
S3: More coordinated and professional delivery of health services to the patient	O3: Increasing global competition in the health sector
S4: Significant cost savings and operational benefits to the traditional healthcare system by developing e-health services	O4: Increased patient satisfaction
S5: Preventing medical errors, safer, transparent and flexible healthcare processes	O5: Increasing the efficiency of the system with remote disease management
Weaknesses:	**Threats:**
W1: Lack of exemplary practices in the sector and in our country, the lack of equal use of digitalization in the health sector in all dimensions	T1: The risk of cyber-attacks brought about by the digital environment
W2: Lack of confidence in innovative technology or lack of knowledge towards new technologies	T2: With the rapid advancement of technology, the risk that the technology used will become obsolete very quickly
W3: Lack of investments in this area	T3: Failures due to maintenance and updates in technological systems
W4: Lack of legal/regulatory standards	T4: Programming errors, incorrect inputs and incorrect progress of processes/analysis

5. Results and Discussion

After creating the SWOT analysis, evaluations were taken from three experts in different formats as follows: DM1 gives an ordering vector. DM2 evaluates each SWOT group and factor in linguistic terms. DM3 gives an importance degree vector. The results of SWOT groups and factors are given in Table 4.

Table 4. Results for SWOT groups and factors

SWOT Groups	Group weights	SWOT factors	Local wights	Global weights
Strengths	0.275	S1	0.243	0.0669
		S2	0.187	0.0515
		S3	0.201	0.0554
		S4	0.167	0.0460
		S5	0.202	0.0556
Weaknesses	0.250	W1	0.245	0.0613
		W2	0.264	0.0661
		W3	0.259	0.0647
		W4	0.232	0.0579
Opportunities	0.258	O1	0.198	0.0510
		O2	0.211	0.0544
		O3	0.176	0.0453
		O4	0.220	0.0567
		O5	0.195	0.0502
Threats	0.217	T1	0.232	0.0502
		T2	0.276	0.0599
		T3	0.237	0.0514
		T4	0.255	0.0554

From Table 4, we can say that the strengths are the most important group. When we look at the factors, the most important one is "S1: Time savings, real-time monitoring and data processing, predictive modeling, with increased speed in service delivery" which is in the strengths group. After that, the second most important factor is "W2: Lack of confidence in innovative technology or lack of knowledge towards new technologies", the third one is "W3: Lack of investments in this area".

After SWOT factors are evaluated, alternative strategies are developed as follows benefiting from the literature review and expert opinions:
SO1: Collaboration between departments should be enhanced to take advantage of automation in all healthcare operations.
SO2: A development roadmap should be created by accurately analyzing which technologies will be integrated into which processes in health systems.
WO1: Training courses should be organized to increase the level of education and awareness about innovative technologies.
WO2: Equipment and manpower should be provided to increase digital investments for the healthcare sector.
ST1: In order to ensure the use of digital networks in health processes of all sizes, technical and economic feasibility studies should be carried out, software development according to user needs, and efforts to increase efficiency and effectiveness should be given importance.
ST2: Technology should be integrated by building a strict firewall and security measures in order to eliminate the risks of cyber-attacks to be experienced with digitalization.
WT1: Timely maintenance, backup and control studies should be planned in order to prevent malfunctions caused by technological systems.
WT2: A long-term and realistic plan should be established to connect the information contained in the old systems to the new systems.
Alternative strategies were evaluated by DMs with MPR according to each factor. The importance of each alternative is computed by using TOPSIS methodology. The final ranking is shown in Table 5.

Table 5. The ranking of strategies

Alternatives	Ci+	Rank
SO1	0.476	3
SO2	0.478	1
WO1	0.477	2
WO2	0.348	6
ST1	0.357	5
ST2	0.406	4
WT1	0.285	8
WT2	0.338	7

From Table 5, it is seen that "SO2: A development roadmap should be created by accurately analyzing which technologies will be integrated into which processes in health systems." is the most important strategy.

6. Conclusion

Today, the use of innovative technologies is seen as an important determinant in increasing the quality of health services and patient safety. Along with the strengths that the use of these technologies will bring, their weaknesses and opportunities/threats should also be analyzed, and progress should be made in line with appropriate strategies. SWOT analysis is the most prominent strategic evaluation methods in the literature. When the literature is examined, it was seen that SWOT analysis was not performed with MPR integrated DEMATEL and TOPSIS in the field of the use of digital technologies in the health sector.

For this reason, in this study, a SWOT analysis of the use of digital technologies in the health sector was made. SWOT factors were evaluated with the MPR DEMATEL method, and alternative strategies were prioritized with MPR TOPSIS. It is one of the results of the study that importance should be given to the strengths it will provide for the effective use of digital technologies. In addition, in order to benefit from technology in the most effective way, it will be important to create a development roadmap first. In the future, this study can be expanded by taking the opinions of more experts, and a more detailed study can be made by increasing the SWOT factors.

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