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Original Research Article

Enhancing competitive advantage through a strategic product portfolio and design for variety in weather radar products

Marzieh Azami[1]*, Mahdi Karbasian[2], Sareh Yousefian[1]

[1]Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[2]Department of Industrial Engineering, Malek Ashtar University of Technology, Tehran, Iran

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***Correspondence:**
Dr. Marzieh Azami,
E-mail: mazami72@yahoo.com

ABSTRACT

Background: In today's competitive industrial landscape, companies are focusing on developing diverse product portfolios to maintain a competitive edge. This trend has led to the adoption of product portfolio strategies aimed at enhancing customer satisfaction and optimizing resource utilization.
Methods: This study introduces a model to enhance the design of weather radar products by integrating DEMATEL and Goal Programming (GP). The methodology involves identifying key indicators of variety in weather radar design, assessing component interdependencies, and determining component weightage for optimal functionality and cost-effectiveness.
Results: The DEMATEL and GP approach proved effective in optimizing the product family structure for weather radar systems. Key results include the identification and prioritization of variety indicators, evaluation of component interdependencies, and determination of component weightage, resulting in a more precise and operational design.
Conclusions: The proposed model for weather radar variety enhances customer satisfaction, meets market demands, and addresses the challenges of dynamic customer needs. This methodology offers valuable insights into managing product variety and complexity, enabling designers to quickly adapt to evolving customer requirements.

Keywords: DEMATEL, Design for variety, Goal programming, Quality function deployment, Modularity

INTRODUCTION

In the dynamic business environment of today, companies must design and develop a range of products that can effectively compete, be distributed, and sustain in the market. To optimize the product portfolio efficiently and with minimal risk, a model based on design and risk indicators becomes imperative. The use of flexible and agile systems in products and manufacturing processes is essential to achieve manufacturing variety and a model for measurement. Modular product family development methods necessitate a wealth of information and data, which may not always align. Compatible data modeling can facilitate simple changes across all affected tools, identify redundant information, and establish networking between different data sources.

Introduction of radar types

Radar systems are essential for various applications, including weather monitoring, defense, and navigation. A weather radar, specifically, is a crucial tool for meteorologists and climatologists to track and predict weather patterns. It consists of several components, each with a unique role in the system's functionality.

Transmitter

This component generates an electromagnetic (EM) signal, such as a short sine wave pulse, which is modulated to provide the desired waveform for detection. The waveform should create a stable signal with adjustable bandwidth, high efficiency, and reliability.

Antenna

The radar antenna is a distinct and vital part of any radar system, responsible for creating a parabolic shape to guide signals in the direction of the target. It intercepts part of the energy transmitted by the target and reradiates it back to the radar receiver.

Receiver

The receiver collects the reradiated energy from the antenna, records it using a data recorder, and processes it to determine the presence of the target using the processor's display and location radar.

These components work together to detect and analyze weather patterns, providing valuable data for weather forecasting and storm tracking. Understanding the roles and interactions of these components is essential for designing and optimizing weather radar systems.

In this research, the focus is on developing a model for the variety of a weather radar using the DEMATEL and GP approach. By identifying and prioritizing various external and internal indicators and drivers effective in the design of a weather radar, a more precise and operational design for variety can be achieved, ultimately benefiting both customers and manufacturers in today's competitive markets.

A review of the latest research conducted on the subject

The latest research on the subject of product variety and its management in the context of customer satisfaction and competition has yielded significant insights. Liu et al introduced a decision-making method using the Analytic Network Process (ANP) and Goal Programming (GP) methods, which allows for the hierarchical and interdependent nature of the product design process to be considered. This approach aims to reduce design costs and increase efficiency by reusing product designs and expanding product portfolios.[1]

Galizia et al proposed an innovative decision support system for the design and selection of product operating systems that better management of trade-off between operating system types and the number of assembly/disassembly tasks creates a product platform and can manage product variety by trying to reconfigure and customize the operating systems.[2]

Saaty et al developed the Analytical Network Process (ANP) technique, which is an improvement over the Analytic Hierarchy Process (AHP) method. Both techniques prioritize elements based on pairwise comparisons, but the ANP model has no specific and predictable structure, unlike the AHP model.[3] The DEMATEL method, first designed by Fontela and Gabus, is used to determine the effect of criteria against constraints and normalize the unweighted super matrix ANP. This method establishes relationships and interdependence among the criteria.[4]

ElMaraghy et al proposed a foundation for managing product variety and its complexity throughout the product life cycle, focusing on design and manufacturing to meet customer needs within budget and time constraints.[5] Kipp and Krausein conducted research to efficiently support design engineers in developing and improving products with a high number of variables.[6] Hanna et al emphasized the importance of visualization-oriented methods and tools for achieving a variety-oriented product structure.[7]

Baylis et al proposed a decision support system for the design and selection of product operating systems that better manage the trade-off between operating system types and the number of assembly/disassembly tasks, creating a product platform and managing product variety by reconfiguring and customizing operating systems.[8] Hsiao et al divided the modular architecture into two stages, using the Interpretive Structural Modeling (ISM) method to modulate and cluster parts and relationships between parts numerically, and then using cluster analysis and ANP to calculate performance and determine the optimal weighting.[9]

Kuchenhof et al proposed an approach for creating a product structure-based system that increases generational variety based on the proposed variety-oriented design. The system dynamism shows the subsequent variety of product components by introducing new product features. The growing network is analyzed using the Cytoscape graph.[10]

In summary, the latest research on product variety and its management highlights the importance of decision-making methods, visualization-oriented tools, and modular architecture in managing product variety and complexity. These studies provide a foundation for developing more efficient and effective product design and manufacturing processes that meet customer needs and expectations.

The main objective of this research is to develop a model for the variety of a weather radar using the DEMATEL and GP approach. This model aims to optimize the product family structure by balancing customer needs and budget constraints. The research will achieve this by identifying and prioritizing various external and internal indicators and drivers effective in the design of a weather radar, ultimately benefiting both customers and manufacturers in today's competitive markets.

The sub-objectives of the research are determining variety indicators in the weather radar design; determining how customer and environmental requirements affect the weather radar design; determining the weight and specifying the component affecting and being affected in the weather radar design.

By achieving these sub-objectives, the research will contribute to a more precise and operational design for variety in a weather radar, helping designers address the challenges of responding quickly to dynamic changes in customer needs and increasing complexity resulting from product design changes in a family structure.

Sub-objectives of the research

Identify key indicators of variety in weather radar design to enhance product differentiation and customer appeal, analyze the impact of changing communication dynamics among weather radar components on design flexibility and performance and determine the weightage of product components and their reciprocal influence within the weather radar design to optimize functionality and cost-effectiveness.

By addressing these sub-objectives, the research aims to provide a comprehensive and detailed understanding of how to develop a model for weather radar variety using the DEMATEL and GP approach. These objectives will contribute to a more precise and operationally efficient design process, enabling designers to adapt quickly to evolving customer needs and navigate the complexities of product design changes within a family structure.

Research questions

In this research, the following main question is raised and the result of the research is the answer to it. In line with the main question, sub-questions are also raised, and answering these questions in the research will determine the answer to the main question.

Main question

How can a model be developed for enhancing the variety of a weather radar using the DEMATEL and GP approach?

Sub-questions

What specific indicators contribute to variety in product design, particularly in the context of weather radar systems? How do changing communication dynamics among weather radar components impact design flexibility and overall system performance? In what ways can the weighting of product components be determined to optimize the design of a weather radar, considering both its influences and dependencies within the system?

By addressing these research questions, the study aims to provide valuable insights into developing a structured and efficient model for enhancing the variety of weather radar systems, ultimately benefiting both industry stakeholders and end-users.

METHODS

The methodology employed in this research is designed to develop a model for the variety of a weather radar using the DEMATEL (Decision-Making Trial and Evaluation Laboratory) approach and Goal Programming (GP). The methodology aims to optimize the product family structure by balancing customer needs and budget constraints. This research started in May 2022 and ended in August 2023.

To achieve this, the research employs the steps that identifying variety indicators: The research identifies key indicators of variety in product design, focusing on weather radar systems; assessing component interdependencies: the study evaluates the impact of changing communication dynamics among weather radar components on design flexibility and overall system performance; determining component weightage: The research determines the weightage of product components and their reciprocal influence within the weather radar design to optimize functionality and cost-effectiveness.

The methodology is based on the DEMATEL and GP approaches, which are integrated to develop a comprehensive model for weather radar variety. The DEMATEL approach is used to determine the effect of criteria against constraints and normalize the unweighted super matrix ANP, establishing relationships and interdependence among the criteria. The GP method is employed to optimize the product family structure by balancing customer needs and budget constraints.

The research also incorporates a case study to explain the operational details of the proposed methodology. The case study demonstrates the application of the DEMATEL and GP approaches in a real-world context, providing valuable insights into the development of a model for weather radar variety.

By following this methodology, the research aims to contribute to a more precise and operational design for variety in a weather radar, helping designers address the challenges of responding quickly to dynamic changes in customer needs and increasing complexity resulting from product design changes in a family structure.

Research experts

The information required to form product design structure matrices and experts in this field are given below: The information required to form product design structure matrices and experts in this field are given below:

Industrial engineer: It concerns a position that demands 18 years of work experience and is filled by 1 employee.

Electrical engineer: It is one of the positions that demand work experience of at least 20 years and it is occupied by 1 person.

Telecommunication engineer: This position reports 15 years of work experience; 1 incumbent.

Management: This post bears seniority 10 years of work experience and the post is manned by 1 person.

Electronic engineer: It has a work experience requirement of 18 and is occupied by 1 worker.

Implementation of the proposed flexible product design approach

The proposed flexible product design approach for weather radar systems is implemented in a three-step process:

Identifying and prioritizing variety indicators: The research identifies key indicators of variety in product design, focusing on weather radar systems. These indicators are prioritized using a combination of the DEMATEL method and goal programming (GP) methods. The DEMATEL method is used to determine the effect of criteria against constraints and normalize the unweighted super matrix ANP, establishing relationships and interdependence among the criteria. The GP method is employed to optimize the product family structure by balancing customer needs and budget constraints.

Assessing component interdependencies: The study evaluates the impact of changing communication dynamics among weather radar components on design flexibility and overall system performance. This step involves analyzing the relationships between components and their impact on the system's adaptability to dynamic customer needs.

Determining component weightage: The research determines the weightage of product components and their reciprocal influence within the weather radar design to optimize functionality and cost-effectiveness. This step involves calculating the weight of each component based on its influence on other components and the overall system performance.

These steps are applied in a case study to demonstrate the operational details of the proposed methodology. The case study illustrates the application of the DEMATEL and GP approaches in a real-world context, providing valuable insights into the development of a model for weather radar variety.

By following this implementation process, the research aims to contribute to a more precise and operational design for variety in a weather radar, helping designers address the challenges of responding quickly to dynamic changes in customer needs and increasing complexity resulting from product design changes in a family structure.

Market planning

Determination of key specifications

The product studied in this research is two models of pulsed and continuous-wave radar. The approach presented in this research was investigated for the fixed model. During interviews with experts and the design team and considering the competitive market and changes in customer needs, the key specifications of the intended product platform and the budget limit in the design of this radar were determined. The results for the radar model are shown in Table 1.

Table 1: Determining the optimal life of the product platform.

Type of radar	Receive and send signal (db)	Transmission power (db)	Frequency (GHz)	Image distance resolution (m)
Pulsed radar	77	24	24	6000
Continuous radar	54	35	35	12000

Provision of key customer components

Through interviews with experts and asking for designers' comments, the effective factors in designing the list of key components desired by the customer are categorized by their respective component names as follows: The IF amplifier is referred to as component A, the RF amplifier as component B, the Duplexer as component C, the Tracker as component D, the Mixer as component E, the Oscillator as component F, the Video amplifier as component G, and the Display as component H.

Prediction of possible changes

In this step, the changes in the customer's needs are evaluated under the supervision of experts and the design team. The result of the interview with the designers is shown in Table 2.

Table 2: Estimation of changes expected by customers by engineering criteria.

Engineering criteria	Qualitative estimation of changes expected by customer	Considered equivalence
Receive and send signal (db)	L	3
Transmission power (db)	H	9
Frequency (GHz)	H	9
Image distance resolution (m)	M	6

Table 3: QFD matrix, relationship weight, and GVI matrix.

Engineering criteria	Components							
	Display	**Video amplifier**	**Oscillator**	**Mixer**	**Tracker**	**Duplexer**	**RF amplifier**	**IF amplifier**
QFD matrix								
Receive and send signal (db)		*	*			*	*	*
Transmission power (db)						*	*	*
Frequency (GHz)			*	*	*	*		
Image distance resolution (m)	*							
Cost	*	*	*	*	*	*	*	*
Relationship weight matrix								
Receive and send signal (db)		3	1			3	3	3
Transmission power (db)						6	9	9
Frequency (GHz)			9	6	3	9		
Image distance resolution (m)	6							
Cost	6	6	9	3	6	3	6	6
GVI matrix								
Receive and send signal (db)		3	1			3	3	3
Transmission power (db)						6	9	9
Frequency (GHz)			9	6	3	9		
Image distance resolution (m)	6							
Cost	6	6	9	3	6	3	6	6
GVI	12	9	19	9	9	21	18	18

Approach of QFD structure

QFD matrix

In this stage of research, the relationship between engineering criteria and components used in design is shown. Since the cost is also an external driver for the product, it is added to the engineering criteria. This relationship is shown in Table 3.

Calculation of GVI

Weighting the requirements communication matrix

To determine the numerical value of GVI, according to the changes required for each component, based on Table 7 and under the supervision of experts, the QFD communication matrix relationship of Table 5 is converted into numbers and the power level of each product element is determined. The values of these communication s are given in Table 3.

Calculating the value of the index

To determine the value of GVI, it is sufficient to calculate the sum of each column of the matrix in Table 7. By adding a row to the end of the weight matrix, the calculated GVI value is noted under each component. This method is used according to Martin and Ishii's article in 2000. Table 3 shows this matrix. By investigating the results of the matrix, it can be seen that in the case of the studied camera, the GVI value, for example, for the duplexer component, is 30. These results indicate that there are components that require higher levels of redesign to meet future specifications.

DEMATEL approach

First phase of the communication matrix

According to the identification and preparation of the list of components and commonalities in the previous step, in this step, the communications of these components with each other are evaluated by experts, and the matrix of the following design structure is presented (Table 4).

The two design structure matrices are summed up together and form the input of the DEMATEL communication matrix (Table 5).

Second phase of the main matrix

In this phase of the research, the relationship between the engineering criteria obtained from the first phase and the components used in the design is shown. By normalizing the main matrix and dividing each presentation by the total, the sum of the rows and columns of the numerical communication matrix is obtained (Table 6).

Third phase of the identity matrix

To form an identity matrix, we set the number one on the diagonal and the rest of the cells are set to zero minus the number of each cell of the normal matrix (Table 6). After that, the identity matrix is inverted (Table 6). Then, the normal matrix is multiplied by the inverse matrix (Table 6).

Table 4: Matrix of design structure.

	A	B	C	D	E	F	G	H
Pulsed radar								
A		1	0	1	1	0	0	0
B	1		1	0	1	0	0	0
C	0	1		1	0	0	0	0
D	1	1	1		0	0	0	0
E	1	1	0	0		1	0	0
F	0	0	0	0	1		0	0
G	0	0	0	1	0	0		1
H	0	0	0	0	0	0	1	
Continuous wave								
A		1	0	1	1	0	0	0
B	0		0	0	0	0	0	0
C	0	0		0	0	0	0	0
D	1	1	0		0	0	1	0
E	1	0	0	0		1	0	0
F	0	0	0	0	1		0	0
G	0	0	0	1	0	0		0
H	0	0	0	0	0	0	0	

Table 5: The first phase of forming the numerical communication matrix.

W	A	B	C	D	E	F	G	H
A	0	2	0	2	2	0	0	0
B	1	0	1	0	1	0	0	0
C	0	1	0	1	0	0	0	0
D	2	1	1	0	0	0	2	0
E	2	1	0	0	0	2	0	0
F	0	0	0	0	2	0	0	0
G	0	0	0	2	0	0	0	1
H	0	0	0	0	0	0	1	0

Table 6: Normal matrix, identity matrix, inverse of the matrix of one, importance of sub-criterion.

	A	B	C	D	E	F	G	H	I
Normal matrix									
A	0	0.33	0	0.33	0.33	0	0	0	
B	0.17	0	0.17	0	0.17	0	0	0	
C	0	0.17	0	0.17	0	0	0	0	
D	0.33	0.17	0.17	0	0	0	0.33	0	
E	0.33	0.17	0	0	0	0.33	0	0	
F	0	0	0	0	0.33	0	0	0	
G	0	0	0	0.33	0	0	0	0.17	
H	0	0	0	0	0	0	0.17	0	
Identity matrix									
A	1	-0.333	0	-0.333	-0.333	0	0	0	
B	-0.167	1	-0.167	0	-0.167	0	0	0	
C	0	-0.167	1	-0.167	0	0	0	0	
D	-0.333	-0.167	-0.167	1	0	0	-0.333	0	
E	-0.333	-0.167	0	0	1	-0.333	0	0	
F	0	0	0	0	-0.333	1	0	0	
G	0	0	0	-0.333	0	0	1	-0.167	
H	0	0	0	0	0	0	-0.167	1	
Inverse of the matrix of one									
A	1.601	0.808	0.243	0.648	0.752	0.251	0.222	0.037	
B	0.411	1.277	0.246	0.201	0.394	0.131	0.069	0.011	
C	0.188	0.313	1.098	0.277	0.129	0.043	0.095	0.016	
D	0.715	0.603	0.344	1.463	0.381	0.127	0.502	0.084	
E	0.678	0.542	0.137	0.281	1.481	0.494	0.096	0.016	
F	0.226	0.181	0.046	0.094	0.494	1.165	0.032	0.005	
G	0.245	0.207	0.118	0.502	0.131	0.044	1.201	0.200	
H	0.041	0.034	0.020	0.084	0.022	0.007	0.200	1.033	
TC	A	B	C	D	E	F	G	H	
A	0.601	0.808	0.243	0.648	0.752	0.251	0.222	0.037	1.409
B	0.411	0.277	0.246	0.201	0.394	0.131	0.069	0.011	0.688
C	0.188	0.313	0.098	0.277	0.129	0.043	0.095	0.016	0.376
D	0.715	0.603	0.344	0.463	0.381	0.127	0.502	0.084	0.807
E	0.678	0.542	0.137	0.281	0.481	0.494	0.096	0.016	0.974
F	0.226	0.181	0.046	0.094	0.494	0.165	0.032	0.005	0.658
G	0.245	0.207	0.118	0.502	0.131	0.044	0.201	0.200	0.401
H	0.041	0.034	0.020	0.084	0.022	0.007	0.200	0.033	0.233
Importance of sub-criterion									
R	1.012	1.085	0.489	0.849	1.146	0.382	0.291	0.049	
D+R	2.421	1.773	0.865	1.657	2.120	1.040	0.692	0.282	
D-R	0.396	-0.396	-0.113	-0.042	-0.171	0.276	0.109	0.185	

Table 7: Collected key specifications.

Specifications	Affecting	Being affected	Cost	GVI normalize
IF amplifier	1.409	1.012	35	0.157
RF amplifier	0.688	1.085	45	0.157
Duplexer	0.376	0.489	55	0.183
tracker	0.807	0.849	65	0.078
Mixer	0.974	1.146	10	0.078
Oscillator	0.658	0.382	20	0.165
Video amplifier	0.401	0.291	15	0.078
Display	0.233	0.049	25	0.104

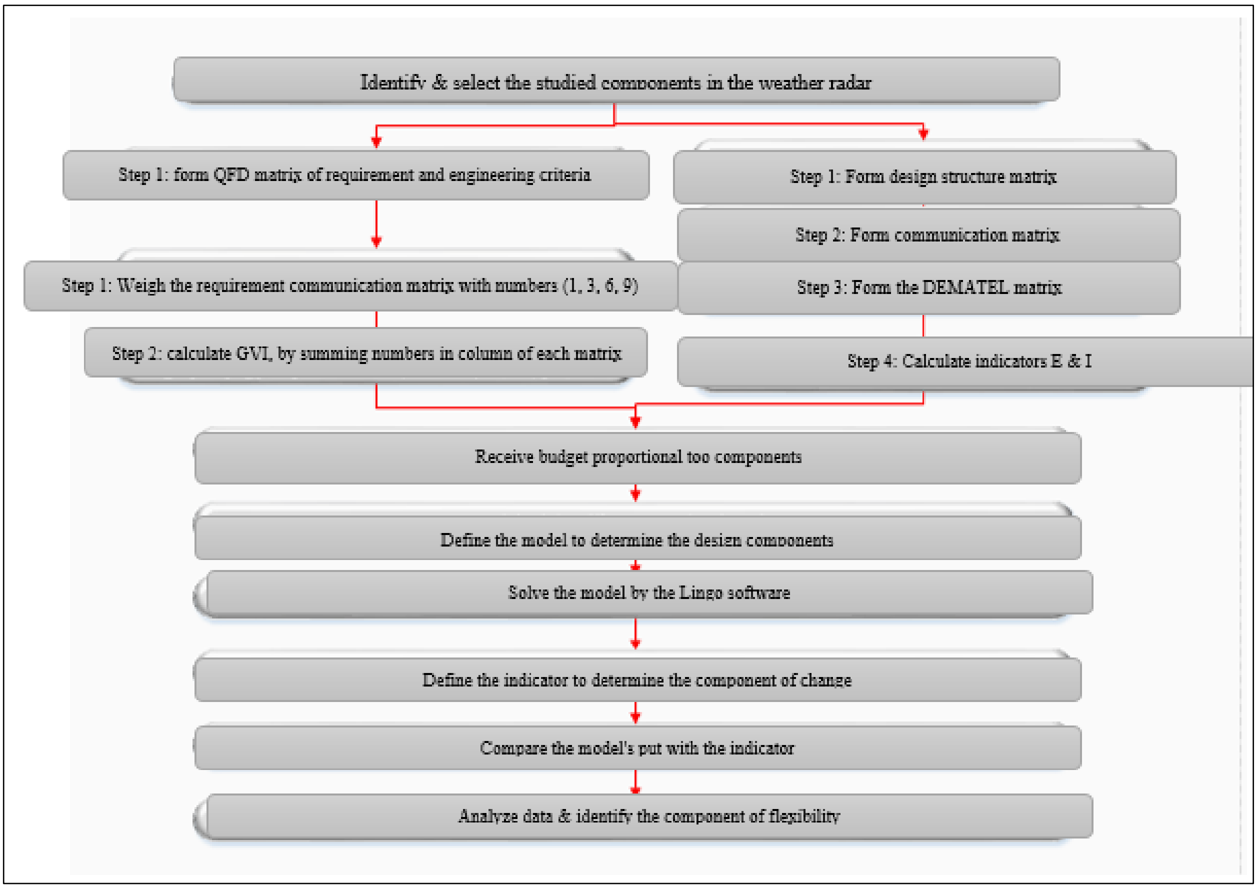

Figure 1: Steps of the research methodology.

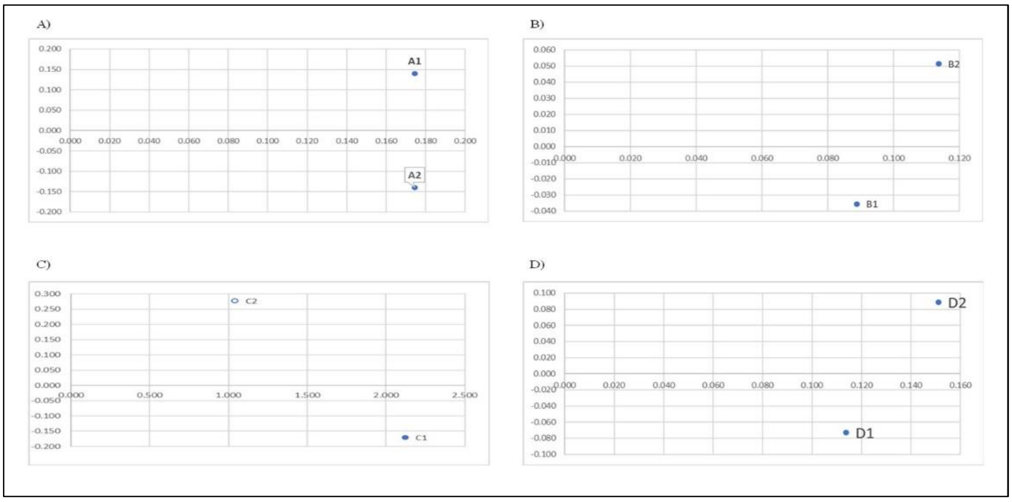

Figure 2: Graphic diagram of indicator A, B, C and 7.

According to Table 7, it can be seen that component A and component E are the most effective.

Planning

The list of indicators obtained from the previous steps, affecting and being affected, is given in Table 8. In this table, a column is also assigned to cost. The cost allocated to each component is determined by the design team.

The graphic diagram of these indicators helps to better visual comparison between the indicators (Figures 2-2). The comparison chart is shown in the figures below. The top of the chart shows the indicators affecting and the bottom shows those being affected.

According to Formula (1), the data in Table (8) and the obtained weights, the goal model for the circuit investigated in the research for the weather radar studied in the research, assuming that the weight of the goals is 0.25 and for each component, an equivalent cost is considered. it is presented and made as follows.

Min $0.25*(d_1^-)+0.25(d_2^-)+0.25(d_3^-)+0.25(b^+/270)$

s.t

$1.409x_1+0.688x_2+0.376x_3+0.807x_4+0.974x_5+0.658x_6+0.401x_7+0.233x_8+d_1^- - d^+_1=1$

$1.012x_1+1.085x_2+0.489x_3+0.849x_4+1.146x_5+0.382x_6+0.291x_7+0.049x_8+d_2^- - d^+_2=1$

$0.157x_1+0.157x_2+0.183x_3+0.078x_4+0.078x_5+0.165x_6+0.078x_7+0.104x_8+d_3^- - d^+_3=1$

$35x_1+45x_2+55x_3+65x_4+10x_5+20x_6+15x_7+25x_8+b^- - b^+=270$

X_i Ɛ [0, 1]

Table 8. Solution results in lingo, normalized cost, indicator α.

Component	Results	Normal cost	Indicator α
IF amplifier	1	0.130	0.062
RF amplifier	1	0.167	0.081
Duplexer	1	0.204	0.171
Tracker	1	0.241	0.041
Mixer	1	0.037	0.036
Oscillator	1	0.074	0.148
Video amplifier	1	0.056	0.104
Display	1	0.093	0.277

Data interpretation

In this stage, to identify the component with a higher change priority, the indicator α is calculated for each component. This indicator was defined in the third chapter. But before calculating the indicator α, it is necessary that all design data be normal. Therefore, the amount of data related to design cost is also normalized. The results are shown in Table 8. The results of GVI indicate that the mixer has the highest value; that is, it is a component that needs to be changed and redesigned. Therefore, for the flexible design of the product, it is necessary to design this modular component, and for this purpose, the indicators affecting and being affected in this component need to be reduced.

The value of the indicator α was calculated for all components and the results of the indicator α are given in Table 8.

The output of the indicator α shows that the display has the highest value and according to the explanations related to defining the indicators and considering the cost for the design, display is the component that needs to be redesigned.

RESULTS

The research presents a methodology for developing a model for weather radar variety using the DEMATEL and GP approach. The proposed model aims to optimize the product family structure by balancing customer needs and budget constraints. The following key results are obtained:

DEMATEL and GP methodology: The DEMATEL method is used to determine the effect of criteria against constraints and normalize the unweighted super matrix ANP, establishing relationships and interdependence among the criteria. The GP method is employed to optimize the product family structure by balancing customer needs and budget constraints.

Identifying and prioritizing variety indicators: The research identifies key indicators of variety in product design, focusing on weather radar systems. These indicators are prioritized using the DEMATEL and GP methods, resulting in a more precise and operational design for variety.

Assessing component interdependencies: The study evaluates the impact of changing communication dynamics among weather radar components on design flexibility and overall system performance. This analysis helps to optimize the product family structure by considering the relationships and interdependencies between components.

Determining component weightage: The research determines the weightage of product components and their reciprocal influence within the weather radar design to optimize functionality and cost-effectiveness. This step involves calculating the weight of each component based on its influence on other components and the overall system performance.

Case study: The research includes a case study to demonstrate the application of the proposed methodology in a real-world context. The case study illustrates the operational details of the proposed methodology, providing valuable insights into the development of a model for weather radar variety.

By following this methodology, the research contributes to a more precise and operational design for variety in a weather radar, helping designers address the challenges of responding quickly to dynamic changes in customer needs and increasing complexity resulting from product design changes in a family structure.

DISCUSSION

The research aimed to develop a model for enhancing the variety of weather radar systems using the DEMATEL and GP approach. The proposed model aimed to optimize the product family structure by balancing customer needs and budget constraints. The key results obtained from this study include the identification and prioritization of variety indicators, the assessment of component interdependencies, and the determination of component weightage. These findings contribute to a more precise and operational design for variety in weather radar systems, helping designers address the challenges of responding quickly to dynamic changes in customer needs and increasing complexity resulting from product design changes in a family structure.

DEMATEL and GP methodology

The DEMATEL method was used to determine the effect of criteria against constraints and normalize the unweighted super matrix ANP, establishing relationships and interdependence among the criteria.[3] The GP method was employed to optimize the product family structure by balancing customer needs and budget constraints.[11] This methodology provides a structured approach to managing product variety and complexity, aligning with the findings of Hsiao et al, who used the Interpretive Structural Modeling (ISM) method to modulate and cluster parts and relationships between parts numerically.[1,9]

Identifying and prioritizing variety indicators

The research identified key indicators of variety in product design, focusing on weather radar systems [10] These indicators were prioritized using the DEMATEL and GP methods, resulting in a more precise and operational design for variety. This approach is similar to the methodology proposed by Kuchenhof et al, who created a product structure-based system that increases generational variety by introducing new product features.[12] The growing network was analyzed using the Cytoscape graph, highlighting the importance of visualization-oriented tools in managing product variety and complexity.

Assessing component interdependencies: The study evaluated the impact of changing communication dynamics among weather radar components on design flexibility and overall system performance.[6] This analysis helps to optimize the product family structure by considering the relationships and interdependencies between components. This finding is supported by the work of Baylis et al, who used a Pareto front of maximum commonality and strategic modularity to select product family platforms.[8]

Determining component weightage

The research determined the weightage of product components and their reciprocal influence within the weather radar design to optimize functionality and cost-effectiveness.[4] This step involved calculating the indicator α for each component to identify the one with the highest change priority. The results indicate that the mixer has the highest value, indicating it is a component that needs to be changed and redesigned. This approach aligns with the methodology proposed by ElMaraghy et al, who used cluster analysis and ANP to calculate performance and determine the optimal weighting.[5]

In conclusion, the research contributes to a more structured and efficient model for weather radar variety by integrating the DEMATEL and GP approaches. The findings provide valuable insights into managing product variety and complexity, enhancing the ability of designers to adapt quickly to evolving customer needs and navigate the complexities of product design changes within a family structure.

The research presented in this study has several potential limitations that should be considered when interpreting the findings and applying the proposed methodology. Firstly, the scope of the research is limited to the development of a model for enhancing the variety of weather radar systems, and the applicability of the DEMATEL and GP approach may be constrained to this specific product domain. Expanding the evaluation to other types of radar systems or broader product families could require further adaptation and validation of the model. Additionally, the case study used to demonstrate the proposed methodology is focused on a single weather radar system, which may limit the generalizability of the results. Incorporating data and insights from multiple radar models or systems could provide a more comprehensive understanding of the factors influencing product variety. The quality and completeness of the data used in the research, gathered through interviews with experts and design teams, may also be limited by the availability and perspectives of the participants involved. Finally, while the research presents the proposed model and its results, the study does not extensively validate the model's performance in real-world implementation. Further testing and evaluation of the model's effectiveness in improving weather radar variety and meeting customer needs would strengthen the conclusions and practical applicability of the research.

CONCLUSION

The research aimed to develop a model for enhancing the variety of weather radar systems using the DEMATEL and GP approach. The proposed model aimed to optimize the product family structure by balancing customer needs and budget constraints. The key results obtained from this study include the identification and prioritization of variety indicators, the assessment of component interdependencies, and the determination of component weightage. These findings contribute to a more precise and operational design for variety in weather radar systems, helping designers address the challenges of responding quickly to dynamic changes in customer needs and increasing complexity resulting from product design changes in a family structure.

In conclusion, this research advances knowledge and understanding in the field of product variety management by providing a structured and efficient model for weather radar variety that integrates the DEMATEL and GP approaches. The findings offer valuable insights into managing product variety and complexity, enhancing the ability of designers to adapt quickly to evolving customer needs and navigate the complexities of product design changes within a family structure. The case study demonstrates the practical application of the proposed methodology, contributing to a more precise and operationally efficient design process for weather radar systems.

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