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Mathematical modeling to evaluate knowledge management in the development of industrial clusters

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Abstract Industrial clustering refers to the concentration of related industries or companies in a specific geographic area. On the other hand, knowledge management focuses on capturing, organizing, and leveraging knowledge within organizations. In the context of industrial clustering, knowledge management plays a vital role in facilitating collaboration, innovation, and competitiveness among the clustered companies. In the current research, an approach to knowledge management in the development of industrial clusters is proposed. Thus, an integer binary mathematical programming model is presented to select the programs with the highest knowledge-enhancing effect. The proposed model allocates the most important programs in its specialized portfolios. To validate the proposed mathematical model, five types (program portfolio) including training workshop, training course, industrial tour visiting industries, exhibition visiting tour, and participating in the exhibition are considered for ten production units. Each of the programs improves the six types of knowledge of its employees in the fields of design, production, purchasing, finance, marketing, and administration in three skill levels (low, medium, and high). According to the results obtained from solving the model with the GAMS software, the programs are assigned to each cluster. The most important finding of the research is that if the programs are implemented in each production unit separately, the improvement of knowledge is less than when they are implemented as clusters. Therefore, it can be concluded that the proposed model has a suitable efficiency in creating knowledge alignment in the organization with the approach of industrial clusters. Moreover, the results indicate that if these programs are implemented separately, the cost of knowledge promotion would increase significantly. Knowledge management plays a crucial role in nurturing collaboration, innovation, and competitiveness within industrial clusters. It helps cluster members unlock the potential of shared knowledge and resources, leading to mutual benefits and the overall development of the cluster.

Keyword: Knowledge management, Industrial clusters, Group knowledge, Innovative performance, Productivity.

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1 Introduction

Industrial clusters, as one of the most important economic drivers since the 70s, have attracted the attention of many countries to the extent that planning to launch and strengthen industrial clusters has become one of the effective strategies of different countries for economic growth. Interaction and exchange in an industrial cluster can be focused on knowledge, as well as the use of cluster resources and relationships by the company to obtain knowledge management or create new knowledge. Industrial clusters with advanced knowledge and techniques are attractive to new firms. Due to this fact that clusters can strengthen industrial capabilities and knowledge. In the knowledge economy, information and knowledge exchange in clusters can boost the firm's capabilities and lead to the creation of knowledge [1]. An industrial cluster is a new form of organization, which helps to increase regional development. When there are several companies with similar activities and products in a geographical area, it becomes possible to create an industrial cluster. By forming a cluster, companies will be able to decrease their investment costs, also access to the professional workforce, knowledge and awareness, techniques required to reach the usual suppliers, promotion, and expansion of professional workforce and increased competition will be easier [2]. Necessary conditions for the success of clusters, companies should establish and create networks with information exchange and knowledge sharing [3]. Knowledge management includes the use of all methods through which an organization can control all its knowledge assets, including how to collect information, accumulate data, transfer knowledge, apply knowledge, update, and create knowledge [4]. Knowledge is considered a vital resource for creating a competitive advantage in organizations [5]. Knowledge transfer is the most important process of knowledge management [6]. In a conscious economy, the exchange of information and awareness in a cluster can strengthen and help the capabilities and abilities of companies, produce knowledge, awareness, and innovative functions [7].

In the context of rapidly evolving industrial landscapes, the effective management of knowledge has emerged as a critical factor for the success and sustainability of industrial clusters. Industrial clusters, which are geographic concentrations of interconnected companies, suppliers, and institutions, rely heavily on the sharing and application of knowledge to foster innovation, enhance competitiveness, and drive economic growth [8]. However, the complexities associated with knowledge management—such as the identification, capture, sharing, and utilization of knowledge—pose significant challenges for cluster development [6]. Despite the recognized importance of knowledge management, there is a lack of comprehensive mathematical models that can quantitatively evaluate its impact on the development of industrial clusters [7]. Existing models often fail to account for the dynamic interactions between various stakeholders, the flow of knowledge, and the influence of external factors such as market conditions and technological advancements. Furthermore, the absence of standardized metrics for assessing knowledge management practices within clusters hinders the ability to benchmark performance and identify areas for improvement [9].

According to the aforementioned research, considering today's competitive business environment, to gain a competitive advantage, the performance of companies in all fields should be optimal and productive to provide the basis for their growth and survival. Given that providing an approach to knowledge management in the development of industrial clusters based on mathematical programming has not been addressed and mathematical modeling has not been used as a strong tool to solve such a problem, the main problem of this research is introducing an approach to knowledge management in the development of industrial clusters and its more realistic results, increasing productivity in the industrial

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cluster, obtaining and creating knowledge by stakeholders, creating value in the industrial cluster, and decreasing costs in the industrial cluster.

This research aims to develop a mathematical modeling framework to evaluate knowledge management in the context of industrial cluster development. The model will integrate key variables related to knowledge creation, sharing, and application, as well as the socio-economic factors influencing cluster dynamics. By employing advanced mathematical techniques, such as optimization algorithms and simulation methods, the study will provide insights into how effective knowledge management can enhance the performance and resilience of industrial clusters.

According to the importance mentioned, the main objective of this research is to introduce a suitable model based on mathematical modeling for knowledge management in industrial clusters, and to achieve this goal, the objectives of this research are generally considered as follows:

- Creating an increase in value for technology production units through the optimal allocation of the program to each industrial cluster.
- Decreasing the costs of deploying programs in each portfolio for technology production units.

Also, this research seeks to create main innovations by posing the following questions:

- How can we allocate several knowledge-based programs in certain industrial portfolios to create the most value and the least cost?

Therefore, the unique and valuable contribution of this research is as follows:

- Creating an alignment of knowledge in the organization with the approach of industrial clusters through mathematical modeling.
- Analyzing current costs and investigating the level of improvement in their amount compared to the optimal situation.
- Optimal valuation for allocating programs in each specialized portfolio using mathematical programming.

The outcomes of this research will not only contribute to the theoretical understanding of knowledge management in industrial clusters but also offer practical tools for policymakers and cluster managers to design and implement effective knowledge management strategies. Ultimately, this study seeks to bridge the gap between knowledge management theory and practice, facilitating the sustainable development of industrial clusters in an increasingly competitive global economy.

The rest of the paper is organized as follows. In the second section, a literature review of the main topic of the research is presented. In the third section, the proposed research method, including the introduction of mathematical modeling, is expressed. In the fourth section, a practical example is stated. Finally, in the fifth section, a general conclusion is provided along with suggestions for future research.

2 Literature review

In this part of the research, a review of past studies conducted on the main topic of the research is presented. For example, Wardhani et al. [8] aimed to investigate the direct effect of knowledge management on knowledge-worker productivity and the indirect effect mediated by employees' adaptability and job satisfaction. The data analysis method was carried out using a structural equation modeling (SEM) model with a partial least square (PLS) approach. The results indicate that knowledge management has no significant effect on knowledge-worker productivity, but knowledge management has a significant effect on

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adaptability, and adaptability has a significant effect on knowledge-worker productivity. Knowledge management also has a significant effect on job satisfaction, and job satisfaction also has a significant effect on knowledge-worker productivity. A study was conducted by Salehi et al. [9] to analyze the knowledge management literature in the field of intellectual capital, social capital, and its contribution to the innovation of Iranian companies. For this purpose, the relationship between knowledge management on intellectual capital, social capital, and innovation was investigated using SEM based on data collected from 205 executives, production managers, and marketing managers of Iranian companies. The results suggest that knowledge management has a positive and significant relationship between intellectual capital and social capital. Also, knowledge management had no significant effect on innovation. However, intellectual capital and social capital have a significant effect on innovation. On the other hand, knowledge management has a positive and significant indirect effect on innovation meditated by intellectual capital and social capital. Sardjono et al. [10] stated the purpose of their study was to provide a framework to evaluate the model of knowledge management systems (KMS) used in a government organization, stating that this system can improve employee performance. This research, which is survey in nature, collected data through a questionnaire. The collected data were analyzed quantitatively using descriptive and inferential statistics. The results obtained from the performed processes indicate that variables such as human, process, and technology have a positive effect on employee performance variables. Therefore, from the results of this study, it can be concluded that the three main variables in the implementation of KMS can have a positive effect on improving the performance of employees in government institutions. Budinato [11] aimed to provide a framework to evaluate the KMS model applied in the electricity company and determine the factors and indicators improving employee performance. This study is a survey in nature that collects data through collective assessment using a questionnaire. Also, the collected data were analyzed quantitatively using descriptive and inferential statistics. The results showed that (1) the variable of people has a positive and significant effect on the performance of employees, which the statistical value of 3.207 proves its significance, (2) the variable of process has a positive and significant effect on the performance of employees, which is evident by the statistical value of 2.263, and (3) the variable of technology has a positive and significant effect on the performance of employees, which is shown by the significant statistical value of 4.506. Dinçer et al. [12] analyzed customer expectations in the European banking industry in their study. To achieve this goal, five different criteria were identified. Additionally, the FDEMATEL decision-making approach was used to weigh these criteria and also to identify the extent of their effect on each other. Finally, the FQUALIFLEX approach was used to rank these three options. Husseini and Pham [13] developed an integrated model of total quality management (TQM) and knowledge management (KM) to reduce digital banking financial crimes to increase the bank's reputation. For this purpose, the required data was collected from 100 employees at the level of the executive management team and above working in Malaysian banks, and the data was analyzed through the structural equation modeling technique using SPSS 22.0 and SmartPLS 2.0. The results showed that the integration of comprehensive quality management practices and knowledge management processes helped to increase the reputation of digital banking in Malaysia. Centobelli et al. [14] proposed a three-dimensional fuzzy logic approach to evaluate the level of alignment between the knowledge an enterprise possesses and the knowledge management systems (KMSs) it adopts. The study also aimed to propose the KMSs best suited to reducing misalignment and improving operational performance in terms of efficiency and effectiveness, analyzing the level of alignment between an enterprise's knowledge and its

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KMSs from both the ontological and epistemological points of view. Finally, the proposed methodology was used to develop a software-based knowledge management decision support system (KM-DSS), which was tested on a small and medium enterprise (SME) operating in the high-tech industry. Cepeda-Carrion et al. [15] which was conducted to create value for customers in the organization through the combination of vital processes of knowledge management including absorption capacity, knowledge transfer, and knowledge application, showed that a more dynamic ability to create value in the customer's mind can be achieved through these three vital processes. Torabi and El-Den [16] investigated the role of tacit knowledge sharing and its effect on organizational productivity. Accordingly, a framework was developed and hypotheses were considered that were tested during the implementation of the research, based on the results of which interesting insights were shown about the role of knowledge sharing in organizational productivity. The results of this survey, which was conducted in Kosar Bank in Iran, showed that the willingness of employees to share and, as a result, tacit knowledge sharing, has a direct and positive effect on the organization's productivity. Furthermore, the analyses carried out indicated that not only productivity increases as a result of knowledge sharing, but also the innovative contributions of employees increase as a result of being exposed to knowledge, expertise, and experiences of others. Turina et al. [17] investigated the cluster of agricultural products formed in Italy. Their research was mostly qualitative. The results of the research indicate the fact that the support and performance of support functions such as governmental and legal, private and scientific, and university centers provide the development and growth of the cluster. The performance of clusters is different based on their type. Sarach [18] examining the relationships and communications of an industrial cluster inside and outside the industry, concluded that industrial clusters not only strengthen relationships and organize resources but also lead to the attraction of talent in the region. Mayangsari et al. [19] analyzed the industrial cluster as an entrepreneurial system in the region. They concluded that the industrial cluster is the nurturing place of entrepreneurial culture and the attraction of regional and local talents. Nie and Sun [20] investigated the cost variable in the industrial cluster. They studied the costs of production and formation of the industrial cluster. Putri et al. [21] investigated the development strategy of the industrial cluster in the coastal farming area of Banyuwangi. In their research, while considering and introducing the industrial cluster as a regional development strategy, they examined this strategy in the coastal farming area of Banyuwangi and its development. Mayangsari et al. [22] analyzed the industrial cluster as an entrepreneurial system in the region. They concluded that the industrial cluster is the nurturing place of entrepreneurial culture and the attraction of regional and local talents. Hoffmann [23] studied the impact of inter-company cooperation, industrial support institutions, labor movement, and social relations on the knowledge transfer process in the Brazilian furniture export industrial cluster. Xiong [24] investigated the effect of four factors of knowledge transmitter, knowledge receiver, knowledge gap, and transferable knowledge on inter-organizational knowledge transfer in industrial clusters using the dynamic systems theory and cause and effect network. Moarrefi et al. [25] conducted a study with the aim of cooperation between companies in the form of a cluster from an economic point of view, the results of their research showed that the focus of small and medium-sized economic enterprises is on the industrial cluster, and they cooperate and compete by combining companies and sharing resources and knowledge to improve learning capacities for optimal use of resources and achieving various benefits. In Table 1, the reviewed studies are classified based on research purposes and methods.

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Table 1 Classification of papers based on their purposes and methods

References NO.	Objective						Method						
	Productivity	**Innovation**	**Employee performance**	**Customer value**	**Financial crimes**	**Knowledge Alignment**	**SEM**	**Survey**	**DEMATEL**	**QUALIFLEX**	**Fuzzy**	**DSS**	**Mathematical Modelling**
[8]	❋				❋		❋			❋			❋
[9]		❋						❋				❋	
[10]			❋					❋				❋	
[11]		❋	❋					❋					❋
[12]				❋					❋	❋			
[13]					❋		❋						
[14]		❋				❋					❋	❋	
[15]				❋				❋					
[16]	❋							❋		❋			
[17]						❋							❋
[18]	❋						❋			❋			
[19]		❋						❋		❋	❋		
[20]			❋					❋			❋		
[21]			❋					❋				❋	❋
[22]				❋					❋	❋			
[23]	❋					❋	❋				❋	❋	
[24]		❋		❋									
[25]			❋					❋	❋	❋			❋

2.1 Research gap

In past studies, researchers have focused on using statistical methods based on survey analysis and statistics. According to the investigation carried out, the lack of attention and use of mathematical programming and modeling can be mentioned as the main research gap. Therefore, in this research, by introducing a suitable model for applying knowledge management for industrial clusters using mathematical programming, we seek to increase productivity in the industrial cluster. This causes the stakeholders to create a database in the industrial cluster through the creation of knowledge, leading to an increase in creativity in the industrial cluster.

3 Methods

In this section, the proposed research method based on mathematical programming is described. For this purpose, first, the main steps of the research are introduced, and then the modeling components including indices, parameters, variables, and equations are explained.

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In general, the main steps of the proposed framework are summarized in four steps. These steps are:

Step 1. Investigation of existing domestic and foreign theoretical sources:
- Completion of more studies and research and review of the literature;
- A thorough investigation of the closest studies conducted in this field;

Step 2. Gathering and collection of information:
- Collection of suitable information on important and effective characteristics and parameters in the problem;

Step 3. Modeling of the problem:
- Construction and development of a suitable mathematical model by the characteristics and main assumptions of the problem;
- Coding of the model in a suitable software environment such as GAMS software or any other suitable software;
- Validation of the developed model and analysis of the results using Excel software;
- Sensitivity analysis;

Step 4. Conclusion:
- General summarization of the research results and suggestions for future research.

3.1 Mathematical modeling

In this section, a mathematical model is developed, which can allocate each program in each portfolio by the level of skill in each knowledge so that the greatest value is created. The mathematical model is an integer programming model assigning the most appropriate program to each portfolio through the definition of a binary variable. The important components of this mathematical model are introduced as follows.

3.1.1 Symbols

The symbols of the sets used in this research are listed in Table 2.

Table 2 Sets

Symbol	Definition of set	Range	Number of components in set
f	Tool portfolio	$f=1,....,F$	$f=1,2,3,4,5$
i	Type of knowledge	$i=1,....,I$	$i=1,2,3,4,5,6$
k	Programs	$k=1,....,K$	$k=1,2,...,13$
l	Skill level	$l=1,....,L$	$l=1,2,3$
j	Number of industrial companies in industrial cluster	$j=1,....,J$	$j=1,2,...,10$

Also, the parameters and decision variables of this research are given in Table 3. It should be noted that all the parameters of this research are considered determined and certain. Moreover, the decision variable in this modeling is binary.

Table 3 Definition of parameters and decision variable

Type of element	Symbol	Descriptions
Parameter	C_{kf}	Cost of executing the $k-th$ program from the $f-th$ basket
	A_{kfil}	The monitored percentage of the $k-th$ program from the $f-th$ portfolio on the i-th knowledge with skill l
	B	Budget for the promotion of cluster knowledge in the programming period
	T_{kfl}	Number of participants in program k from portfolio f with skills l
	Q_{kfjil}	Participant in program k from portfolio f from company j with knowledge i and skill l
	E	Maximum number of programs per time period
	Y_{jil}	Ability of company j in knowledge i of skill l
	P_{jl}	Number of employees in company j with skill level l
Decision variable	X_{kf}	If program k is selected from basket f, the value of the variable is one, otherwise it is zero.

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3.1.2 Objective function and equations

The objective function and set of integer programming constraints are developed according to equations 1 to 8.

$$Max\,\mathbb{Z} = \sum_{k=1}^{K}\sum_{f=1}^{F}\sum_{i=1}^{I}\sum_{l=1}^{L} X_{kf} A_{kfil} T_{kfl}$$

$$\sum_{K=1}^{k}\sum_{f=1}^{F} X_{kf} C_{kf} \le B \qquad (1)$$

$$\sum_{k=1}^{K} X_{kf} \le 2 \qquad \forall f \qquad (2)$$

$$\sum_{k=1}^{K} X_{kf} \ge 1 \qquad \forall f \qquad (3)$$

$$\sum_{f=1}^{F}\sum_{k=1}^{K} X_{kf} \le E \qquad (4)$$

$$E \ge F \qquad (5)$$

$$\sum_{j=1}^{J}\sum_{i=1}^{I} Y_{jil} \le T_{kfl} \qquad \forall l \qquad (6)$$

$$\sum_{i=1}^{I} Q_{fkjil} \geq 1 \qquad \begin{matrix} \forall f \\ \forall k \\ \forall l \\ \forall j \end{matrix} \tag{7}$$

$$\sum_{i=1}^{I} Q_{fkjil} \leq 0.3 P_{jl} \qquad \begin{matrix} \forall j \\ \forall l \\ \forall k \\ \forall f \end{matrix} \tag{8}$$

In the above relations, the objective function of the problem, maximum Z, maximizes the value of each program in each portfolio by the skill level in each knowledge. It maximizes the value created from allocating program k from portfolio f in the monitored percentage of the $k-th$ program from the $f-th$ portfolio on the $i-th$ knowledge with skill l using the number of participants in program k from portfolio f with skill l. Constraint 1 is considered the budget constraint of cluster knowledge promotion in the programming period. Constraint 2 guarantees the maximum execution of two programs from each portfolio. Constraint 3 states the execution of at least one program from each portfolio. Constraint 4 guarantees the execution of several programs. Constraint (5) guarantees that the minimum number of programs is greater than or equal to the number of portfolios, Constraint 6 shows the skill capacity in each program. Constraint 7 indicates that there is at least one person from each company of the desired skill i in program k from portfolio f. And finally, Constraint 8 guarantees that there is a maximum of 30% of employees in each skill from one company in the program. The above model is coded in GAMS optimization software and the results are calculated using the CPLEX tool on a personal computer with Intel Corei3 CPU and 4.00GB RAM.

4 Results

4.1. Case study description

In this section, using the proposed model among 10 knowledge-based technology manufacturing companies located in Rasht Industrial City, its usability in knowledge synergy and cost reduction are discussed. Rasht Industry City, located in the northern part of Iran, is a significant industrial hub known for its strategic position near the Caspian Sea. Established to promote economic development, it hosts a variety of manufacturing and production facilities, contributing to the region's growth. The city is characterized by its diverse industries, including food processing, textiles, and machinery, which leverage local resources and talent. Rasht Industry City is designed with modern infrastructure, providing essential services and utilities to support businesses. The Rasht industry area also benefits from proximity to major transportation routes, facilitating trade and logistics. Additionally, the city emphasizes sustainable practices, encouraging industries to adopt eco-friendly technologies. With a focus on innovation, Rasht Industry City fosters collaboration between businesses and educational institutions, enhancing workforce skills. The local government actively supports investment opportunities, making it an attractive destination for entrepreneurs. Overall, Rasht Industry City plays a pivotal role in driving economic growth and job creation in the region.

To implement the developed mathematical model, five portfolios related to the industry are considered. These portfolios are workshops, training, industrial tours visiting industries, visiting exhibition tours, and participating in the exhibition. Each of these portfolios is

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assessed based on the six types of knowledge of its employees in the fields of design, production, purchasing, finance, marketers, and administration to implement programs related to each portfolio based on the three considered skill levels (low, medium, and high). The programs considered for each portfolio are as follows:

- **Workshop portfolio:** design and project management
- **Training portfolio: CRM,** collection of debts, and business management
- **Industrial tour portfolio to visit industries:** domestic industries, foreign industries 1 and foreign industries 2
- **Exhibition tour visit portfolio:** domestic and specialized foreign
- **Exhibition participation portfolio:** domestic, provincial, and foreign

A total of 13 programs are considered for the portfolios. The desired data are collected from classified archive documents of 10 knowledge-based companies located in Rasht Industrial City. According to the monitoring conducted among the collected data, all employees are divided into different skill levels. The presence of all manufacturing companies located in clusters in knowledge management projects is mandatory. The knowledge promotion budget for each cluster is determined and limited for each manufacturing company. The participation capacity in each cluster is limited and known. Companies are already prioritized based on existing organizational knowledge. The effect of implementing each tool on each knowledge and skill level is known. Only one program must be selected from each portfolio. Table 4 shows the monitored effect of programs on people's knowledge and skills. Table 4 provides a comprehensive overview of the impact of various training programs on individual skill development. It highlights key metrics such as skill improvement percentages, participant satisfaction ratings, and overall program effectiveness. Each entry reflects the correlation between specific programs and the enhancement of skills among participants. This table serves as a valuable tool for assessing the return on investment in training initiatives and identifying areas for further development. Ultimately, it aids organizations in making informed decisions to optimize their training strategies and improve workforce capabilities. Table 5 lists the percentage of participants in each program. Table 5 illustrates the distribution of individuals across various training programs offered by the organization. It presents the percentage of total participants enrolled in each program, allowing for easy comparison of participation rates. This table helps identify which programs are most popular and which may require additional promotion or adjustment. By analyzing these percentages, organizations can better understand participant preferences and align their offerings with workforce needs. Ultimately, this data supports strategic planning for future training initiatives and resource allocation.

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Table 4 Values of the monitored effect of programs and individuals' skills

Portfolio	Program	Capacity				Cost	Design			Production			Purchase			Finance			Marketing			Administration		
		L_1	L_2	L_3	Total		L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Workshop	Design	35	20	15	70	6,000	0.2	0.5	0.3	0.1	0.2	0.2	0	0	0	0	0	0	0.1	0.1	0.1	0	0	0
	Project management	25	15	10	50	6,000	0	0.1	0.2	0.4	0.5	0.7	0.2	0.3	0.4	0.1	0.1	0.1	0.2	0.3	0.4	0.1	0.2	0.4
Training	CRM	9	7	7	23	3,000	0.1	0.1	0.1	0	0.1	0	0.1	0.1	0.2	0	0	0	0.4	0.3	0.2	0.4	0.3	0.2
	Collection of debts	33	12	30	75	3,000	0.2	0.2	0	0.2	0.2	0.2	0.1	0.1	0.1	0.4	0.4	0.3	0.1	0.1	0.1	0.1	0.2	0.2
	Business management	5	10	3	18	3,000	0.2	0.1	0.1	0.1	0.1	0.1	0.5	0.4	0.3	0.1	0.1	0.2	0.4	0.3	0.2	0.1	0.1	0.1
Industrial tour visiting industries	Domestic industries	12	5	11	28	5,000	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0	0	0
	Foreign industries 1	12	10	5	27	15,000	0.1	0.2	0	0.5	0.5	0.4	0.1	0.1	0.2	0.1	0.2	0.3	0.1	0.1	0.1	0.2	0.2	0.2
	Foreign industries 2	11	5	9	25	10,000	0.2	0.1	0.1	0.5	0.5	0.4	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2
Exhibition tour visit	Domestic 1	20	15	8	43	10,000	0.1	0.1	0	0.1	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0
	Foreign specialized	19	23	11	53	10,000	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.4	0.3	0.2	0.2	0.1	0.1
Participation in exhibition	Domestic	14	19	12	45	10,000	0.1	0.2	0	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0.5	0.4	0.3	0.2	0.2	0.2
	Provincial	20	15	10	45	30,000	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.6	0.5	0.4	0.2	0.1	0
	Foreign	10	15	10	35	40,000	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.8	0.7	0.6	0.1	0.2	0.1

Table 6 shows the number of human resources working in the production units of the cluster according to the knowledge and skills of each production unit. Table 6 provides a detailed breakdown of the workforce composition within the cluster's production units. It categorizes employees based on their specific knowledge areas and skill sets, highlighting the diversity and expertise available. This data is crucial for understanding the strengths and gaps in human resources, enabling targeted training and development initiatives. By assessing the distribution of skills, organizations can optimize team assignments and enhance overall productivity. Ultimately, this information supports strategic workforce planning and fosters a culture of continuous improvement within the cluster.

Table 5 Percentage of participants in each program

Production Unit	Design			Production			Purchase			Finance			Marketing			Administration			Total (person)
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	
1	2	1	0	1	3	1	0	1	1	1	1	1	1	1	1	1	1	1	19
2	2	2	2	1	3	1	1	1	1	1	2	1	1	1	1	1	2	1	25
3	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	1	2	1	21
4	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	19
5	1	1	1	1	1	2	2	1	1	1	2	1	1	1	1	1	1	1	21
6	2	2	1	3	3	2	1	1	1	1	1	2	1	1	1	1	1	1	26
7	4	2	2	2	3	1	1	2	1	1	1	1	1	1	1	1	1	1	27
8	2	1	1	2	2	1	1	1	1	1	1	2	1	1	1	1	1	0	21
9	2	2	3	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1	24
10	2	1	1	1	3	2	2	1	1	1	2	2	1	1	1	1	1	1	25

Table 6 Number of human resources working in production units of the cluster by knowledge and skills

Production Unit	Design			Production			Purchase			Finance			Marketing			Administration			Total (person)
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	
1	5	5	5	5	10	10	10	8	8	9	9	2	9	2	9	9	5	5	125
2	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	88
3	9	9	9	2	2	2	10	10	10	10	10	10	2	5	3	5	5	2	115
4	10	10	2	2	2	2	2	2	10	10	8	10	10	2	2	2	12	2	100
5	9	12	10	15	10	10	12	10	8	9	9	10	5	5	5	10	9	12	170
6	8	10	10	9	10	10	12	15	8	9	9	10	12	10	10	10	8	9	179
7	10	14	10	2	2	2	2	10	2	2	10	10	12	10	9	8	7	5	127
8	5	10	2	9	9	5	5	9	8	2	9	5	5	5	5	5	1	1	100
9	9	9	2	2	12	8	10	15	14	12	12	12	12	10	10	9	8	7	173
10	9	8	7	10	15	13	15	14	14	12	10	13	12	10	11	15	10	12	210

According to the collected data, the second production unit has the least number of specialists, and the 10^{th} production unit has the largest number of specialists.

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4.2 Computational results of mathematical modeling

Taking into consideration the aforementioned issues in the mathematical model of integer programming developed and with the implementation of the model, the optimal solution for the model is obtained. Given that the goal is to allocate the most appropriate program to each portfolio, it can be stated that the mathematical model is a type of allocation problem. For this purpose, a binary solution is used to select or not select each program in each portfolio. So, if the desired program is selected in each portfolio, the program assigns a value of 1 to it, otherwise a value of zero. Table 7 shows the computational solution results of the mathematical programming model in GAMS software using the CPLEX tool.

Table 7 Output of the computational solution of the mathematical model

Program No.	Program name	Allocated portfolio	Variable value
1	Design	Workshop	$X_{11} = 1$
5	Business Management	Training	$X_{52} = 1$
8	Foreign industries 2	Industrial tour visiting industries	$X_{83} = 1$
10	foreign specialized	Exhibition tour visit	$X_{10\,4} = 1$
11	Domestic	Participation in the exhibition	$X_{11\,5} = 1$

Therefore, taking into account the set of solutions obtained as $X_{11} = 1$, $X_{52} = 1$, $X_{83} = 1$, $X_{10\,4} = 1$, $X_{11\,5} = 1$, as the optimal solution, the objective function value—which is the created value—is calculated at 1500. As it was supposed to assign one program to each portfolio, it can be seen that only one program is assigned to each portfolio. For example, in the first portfolio where two design and project management programs are defined, only the design program is assigned and the project management program is left out of the agenda. In the second portfolio, where CRM programs, collection of debts, and business management are defined, only the business management program is allocated and other programs in this portfolio are left out. In the third portfolio, which includes programs for domestic industries, foreign industries 1, and foreign industries 2, only the program for foreign industries 2 is allocated and other programs are left out of the programming agenda. In the fourth portfolio, which includes domestic and foreign specialized programs, only foreign specialized programs are allocated to this portfolio, and finally, in the fifth portfolio, which includes domestic, provincial, and foreign programs, only the domestic program is allocated to this portfolio and the allocation of other programs is ignored.

4.3 Analysis of computational results and validation of mathematical modeling
A) Comparison based on created value

In this section, based on the calculated results, we consider the programs selected for each portfolio for each company separately. For this purpose, in the programs selected for each

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portfolio, the product of the monitored effect of the programs on people's knowledge and skills (Table 4) in the capacity of participants of the production units in selecting each program (Table 6) and the number of human resources working in the production units of the cluster are calculated according to knowledge and skills separately (Table 7). Table 8 shows the value created for each program separately and synergistically using the proposed model.

Table 8 Values of programs in general and separate modes

Production unit	Programs	Portfolio	Value
Each production unit	Design	Workshop	1500
	Business management	Training	
	domestic	Participation in the exhibition	
	Foreign industries 2	Industrial tour visiting industries	
	foreign specialized	Exhibition tour visit	
All 10 production units	Design	Workshop	204.7
All 10 units	Business management	Training portfolio	233.2
All 10 units	Foreign industries 2	Industrial tour visiting industries	380.7
All 10 units	Foreign specialized	Exhibition tour visit	303.9
All 10 units	Domestic	Participation in the exhibition	233.6

Based on the results in Table 8, given that the proposed model can create an alignment based on the value of knowledge so that the most suitable program in each portfolio is selected based on the skill level of human resources. For example, if all programs are executed in each production unit in the respective portfolios, 1500 units of value will be created. If Foreign Industries Program 2 is used in the industrial tour portfolio, visiting industries in production units will create 380.7 units of value. If other programs are used in each production unit separately, the total value of other programs will be added to this value, so that in this case, the total value is calculated as 1356.1, which is less than the total value calculated by solving the model and suitable allocation of each program to the portfolio. In addition, in Table 9, the value of all programs in each production unit is shown. Also, it shows the total value created for the implementation of all programs in each production unit. For example, if all programs are implemented simultaneously, 1.354 units of value will be created in the first production unit. According to Table 9, the value created from the implementation of all programs in production units is far less than the value created by the proposed model. This suggests that the proposed model can determine the state in which the value created remains in the optimal state. The proposed model will be able to maximize the created value by choosing the most appropriate program based on the capacity and skill of human resources in each production unit.

Table 9 Values of implemented programs in production units

Portfolio	Program	Production unit									
		1	2	3	4	5	6	7	8	9	10
Workshop	Design	15.0	14.8	11.6	10.4	19.8	32.1	33.1	15.5	24.2	28.2

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	Project management	42.0	30.7	25.7	20.2	55.0	73.3	35.4	35.3	56.3	86.6
Training	CRM	19.0	17.0	16.0	15.0	23.0	30.0	28.0	14.0	31.0	36.0
	Collection of debts	26.3	23.0	23.3	21.6	37.9	46.9	32.5	24.0	39.7	57.0
	Business management	22.7	21.1	13.3	19.2	39.2	46.6	38.4	24.0	47.6	60.1
Industrial tour visiting industries	Domestic industries	19.0	16.0	16.0	12.0	26.0	36.0	25.0	21.0	30.0	39.0
	Foreign industries 1	35.0	26.5	21.1	19.4	44.0	63.7	30.3	33.7	43.6	72.2
	Foreign industries 2	34.0	25.6	20.5	17.4	44.3	61.8	31.2	32.2	42.1	71.6
Exhibition tour visit	Domestic 1	23.0	17.0	15.0	13.0	24.0	37.0	24.0	19.0	33.0	45.0
	Foreign specialized	22.0	20.2	20.5	17.8	34.0	44.5	36.8	21.0	37.1	49.3
Participation in exhibition	Domestic	19.1	16.5	13.8	13.8	23.4	34.4	29.7	15.7	30.6	36.6
	Provincial	24.0	21.0	22.0	20.0	33.0	40.0	35.0	24.0	40.0	53.0
	Foreign	53.0	27.0	24.0	24.0	37.0	59.0	48.0	29.0	52.0	65.0
Total	13	354.1	276.4	242.8	223.8	440.6	605.3	427.4	308.4	507.2	699.6

Hence, according to the analysis carried out based on the created values, firstly, the proposed model can create more value, secondly, it will be able to create a value far more than separate values of each of the programs by creating synergy. According to the analyses, it is concluded that the proposed model has a favorable performance in terms of creating value.

B) Comparison based on the created cost

The cost of implementing each program and the total cost of allocating programs in optimal portfolios are described in Table 10. Based on the results obtained, the optimal cost of allocating the "foreign specialized" program to the specialized portfolio of "exhibition tour visit" has the lowest cost with a value of 14,600 units. Furthermore, the highest allocation cost related to the "business management" program for allocation in the specialized training portfolio is 19,000 units. The cost of using any of the programs synergistically according to the proposed model is always lower than the cost of the existing situation. Given that the total cost in the current situation is 226,871.854 monetary units, and it is 86,900 monetary units in the optimal situation, we face a reduction of 139,971.854 monetary units, which is equivalent to 61.6% cost savings.

Table 10 Analysis of the model results

Selected program	Specialized portfolio	Optimal value	Allocation cost	Status quo cost
Design	Workshop	$X_{11} = 1$	18700	20649.948
Business management	Training	$X_{52} = 1$	19000	19291.395
Domestic	Participation in the exhibition	$X_{11\,5} = 1$	17000	51504.809

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Foreign industries 2	Domestic tour visiting industries	$X_{83} = 1$	17600	73295.702
Foreign specialized	Exhibition tour visit	$X_{10\,4} = 1$	14600	62130
	Total cost		86900	226871.854

Thus, according to the analysis conducted based on the created costs, the model will be able to create optimal savings based on the optimal allocation of costs. According to the analysis, it is concluded that the proposed model has a favorable performance in terms of cost.

5 Discussion and conclusion

In this paper, an approach based on mathematical modeling was proposed to evaluate the level of alignment between a company's knowledge and knowledge management systems. The proposed approach can be used to identify the elements of a knowledge management system decreasing inconsistency and improving the operational performance of a company in terms of efficiency and effectiveness of the knowledge management system. The process of assessing the alignment of knowledge management is an essential step in the knowledge management process due to its critical effect on improving the overall performance of a company. The provided framework is an operational tool that may be used to identify the specific situation of a program in small and medium-sized industries to decide on the introduction of appropriate changes to increase the level of alignment between a company's knowledge and knowledge management tools. The proposed mathematical model is capable of assigning the most suitable programs to each industrial portfolio using an integer binary programming among several programs in such a way that the cost of executing all programs simultaneously in each production unit is minimized compared to their separate implementation. Based on the results obtained, the design program is assigned in the workshop portfolio, the business management program in the training portfolio, the domestic program in the exhibition participation portfolio, the foreign industries program in the industrial tour portfolio, and the foreign specialized program in the exhibition tour portfolio. Additionally, by implementing the selected programs for each portfolio for each company separately, the value of using each program in all companies was calculated. Finally, it is shown that if the programs are considered separately in each production unit, the value of implementing the programs will be lower than when the programs are generally placed in different portfolios of the manufacturing companies. Therefore, it can be concluded that the proposed model shows a suitable capability for creating knowledge alignment in the organization. The most important limitations of this research are as follows: It is difficult to include or remove new tools in decision support systems in their current form, considering today's dynamic environment. Also, in this research, several specific and limited programs are considered for some time. Finally, suggestions for the development of the present research are provided in the following. A multi-period programming model that will be able to allocate various programs to portfolios in different periods can be used. Given that we are faced with uncertainty in programming, a model to overcome uncertainty should also be presented so that the developed model is out of the uncertain state and becomes closer to the real world. Using multi-criteria decision-making, the importance of each of the programs in each portfolio and

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their prioritization should be determined to identify the most important program among the considered ones.

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