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Case Report

Identification and Prioritization of the Technology Transfer Risk Factors Using Fuzzy-AHP Method the Case of the Pharmaceutical-food Supplements Industry

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Abstract

Technology Transfer is one of the tools to perform economic activity which involves the processes of technology invention, technology development and technology diffusion. Given the importance of the dietary supplement industry in human and animal health, and its role in the development of agriculture and exports, it is necessary to identify, on one hand, the risks that lead to incomplete transfer of these technologies – which in turn result in the country's technological dependence in this field – and on the other hand, the risks that this issue poses to human health and the environment. These risks must be identified and assessed. In this study we identify and categorize the technology transfer risk in identify and categorize the technology transfer risk factors in the pharmaceutical-food supplements industry. This research is applied in terms of its objective, and from a methodological perspective, it falls under mixed methods research, combining both quantitative and qualitative approaches. The findings of this study are applicable to agricultural research centers, the Ministry of Health, technology policy-making bodies, and technology headquarters related to health and well-being. In order to identify, prioritize, and evaluate technology transfer risks, this research employs the fuzzy AHP (Analytic Hierarchy Process) method. According to the results of the research, thirty-seven risks are identified in the form of five main criteria of risks affecting the pharmaceutical-food supplements industry. Using the prioritization process conducted in the present study, the obtained main criteria include the influence on health, resource accessibility, the essence of technology and its nature, dependence on government policy making and socioeconomic problems and, organizational governance and management capability. Also, the most importance sub-criteria obtained in the research was the "risk of microbial contamination".

Keywords

Technology Transfer Risk, Effective Technology Transfer, Health Technology Assessment, Pharmaceutical-food Supplement, Fuzzy AHP

1. Introduction

Technology Transfer can be said that technological innovation is one of the basic prerequisites and the main source of technology transfer [24].

As such, effective risk management is essential for successful implementation of project. Correct risk management practices along with the new technology deployment should

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be used to identify, assess, and manage the risks, and a proper control should be applied in this regard to increase the likelihood of projects success [20].

According to the American National Research Council on pharmaceutical-food supplements, the optimal supply of mineral substances and vitamins is essential for the health and proper functioning of living organisms since they are responsible for many biological functions in body [27].

Technology development has become one of the strategic elements of the organization in the present era, such that changes affect social, economic and political system more than technology itself. One of the main reasons for the failure of implementation of health information systems is not being demanded by the users. So, knowing the reasons behind the acceptance or rejection of new information system by physicians and other medical team members is important. This information makes it possible for the organization to actively implement reforms to improve the acceptance of new systems. The users' attitudes, as well as getting familiar with the plans and concepts of electronic health records have a significant impact on the success of the implementation of electronic health records [13].

The importance of the food supplements industry in human and animal health, as well as the position of this industry in the development of the agricultural sector and exports makes it necessary to identify the risks causing incomplete transfer of these technologies and consequently, the country dependence on technology in this area. Due to the sensitivity involved in the field of pharmaceutical-food supplements, our purpose in this study is to examine the risks of technology transfer in the production of pharmaceutical-food supplements using the set of standards defined in the Health Technology Assessment (HTA).

2. Technology Transfer and Its Related Risks

Technology Transfer is defined as the utilization and use of technology in a location other than the original location. In other words, technology transfer is a process that causes the technology flow from source to recipient [25].

Typically, there are obstacles ahead of technology transfer, among which, technology management, education and culture system can be mentioned as the most important ones [21].

Bosselmann et al believe that culture is one of the powerful factors affecting the success of technology transfer [4]. Deductive risk, manufacturing process risk, equipment risk, possibilities and facilities as well as project risk are also considered by Toso et al as the types of risks associated with technology transfer. However, change is one of the factors leading to deductive risk. Toso et al also noted the risks of known and unpredictable changes in technology transfer [39].

As well as intellectual property right as the other risks that can be considered in the field of technology transfer. According to Isobe et al, corporate executives tend to achieve overseas benefits from sales and technology costs spent by their companies [19]. Anderson and Gatignon, and Buckley and Casson, on the other hand, argue that such managers do not tend to empower other companies, because they may become competitors that surpass them in accessing their technologies, and grab the competitive leadership position of them [1, 6]. Liebeskind states that companies are not intrinsically concerned about the international technology transfer [23]. However, they are worried about the technology acquisition by potential domestic or foreign competitors. Therefore, companies may have less protection against the technology takeover in some places abroad rather than inside the borders of the country [10, 42]. The technology transfer cost is another risk factor in technology transfer. In his study, according to Coase theorem, companies have an incentive to use their technology in their own company because otherwise, partners are required to pay the costs of monitoring the knowledge usage and this cause risks, as a result of that, partners may violate technology agreements [5]. Transaction cost theory also discusses about the cost of opportunism by technology partners during external development [1, 16, 43]. Moreover, the training cost of an implicit technology to the external organization is considered. Teece has also pointed the importance of transfer costs studying 26 reasons for the international technology transfer [38, 8].

Twenty-nine other risks and its related strategies, affecting the internal environment of the technology receiving organization, were identified through surveys conducted by Jung et al, Lack of personnel and excessive workload, lack of adequate support from the executive and management department, unrealistic budget and program, lack of sufficient knowledge in the field of technology, lack of experience e.g. implicit technical knowledge in conducting the project to introduce the new technology, lack of understanding of the systems where new technology is applied, the poor specification of requirements (unspecified requirements), delays in delivery, lack of new technology verification system, lack of basic technology for the new technology deployment, practical limitations such as unavailability of equipment supply, and finally, supply of equipment from the supplier without enough experience in the industry are some of the risks in this regard [20].

3. Pharmaceutical-food Supplements

Mineral and vitamin supplements are a combination of minerals and vitamins, added to diet to compensate for diet deficiencies. This is because commonly used food items cannot often provide all the nutrients and vitamins needed to maintain health [17]. Given the importance of adding mineral and vitamin supplements to the diets, the commercial production of supplements is common all over the world [37].

According to Pesti et al, the presence of some nutrients in these supplements is one of the reasons for the improvement of the feed conversion ratio when using vitamin and mineral supplements in diets [30].

Based on the findings of Deaton et al and Bye, the use of vitamin supplements can have a protective role in livestock. Horses experience more stress in the exercise seasons, held mostly in spring and summer [11, 7]. Exercise stress, according to Kinnunen et al, sometimes comes to the extent that threatens the horse's sportive ability and the horse fails to continue the tournament despite championship ability. Therefore, it is very important and vital to preserve the horse's ability to compete until the race [22].

The availability and quality of food is very variable due to the seasonal pattern of forage growth. The use of supplements for livestock, dependent on such nutritional sources, is essential especially in dry seasons. According to Mohammed Saleem, high quality dietary supplements are suitable for providing the supplements necessary for dry season and livestock productivity improvements [26, 12].

Nutritionists and horse owners need to be able to balance between the two aspects of horse feeding as a science and an art. The only one qualified for deciding on the full use of horse talent is the person who daily deals with horse. This information is also applicable for nutritionists who are responsible for helping to adjust horse-breeding needs. The Art of nutrition is exactly the ability to recognize individual differences and adjust their relationships [31].

4. The Relationship Between Health Technology Assessment and Technology Transfer Risk Assessment

Technology Innovation has undoubtedly brought significant improvements in the field of health care over the past four decades. These advances can be observed in areas such as biotechnology, antiviruses, surgical techniques, molecular diagnosis, diagnostic imaging, tissue replacement and body organs, wound care, computer technology, etc. helped a lot to improve health care delivery and patient consequences [14]. It should be primarily noted that the term "health technology" does not refer only to medical technologies. In fact, the term "health technology", provides a wide range of interventions for health promotion, including prevention, diagnosis or treatment of diseases, long-term rehabilitation and/or long-term care of patients, plus medicines, equipment, clinical methods and environments based on the definition of the Health Technology Assessment Glossary, edited in 2006 by the International Network of Agencies for Health Technology Assessment Institutions [18]. Governments are facing constant pressures to ensure health financing while supporting innovation due to its necessity in the context of low economic growth, population aging and health technologies development [9].

The wider effects are imaginable for health technologies and the benefits and costs associated with it are assessed in both clinical and economic dimensions. This will help to optimize the use of special interventions, appropriate placement in the care filed and patients take advantage of it. Health technology assessment, traditionally used for expensive medical equipment and expensive medicines, has increasingly focused on assessing a wide range of interventions including therapeutic and surgical procedures, and organizational and supportive devices for care and prevention and to the less extent in public health programs [28]. The fact introduction and technologies diffusion in health care systems has been occurred after technological innovations [32]. The spread and diffusion of health technologies has been coupled with the sharp increase in health care costs. Although the nature of this relationship is complex and evolving, it has been considered as one of the causes of its promotion for the first time [35].

It should be noted that the creation and development of technologies does not necessarily lead to income and health benefits. There are numerous examples of technologies in the history of medicine, medicine and health that have not only created the expected benefits, but also brought disadvantages. It is therefore necessary to ensure that health technologies are properly evaluated and then, effectively applied in health care delivery. Health technology assessment causes decrease the use of technologies that are not safe, inefficient, or technologies that are too costly than the benefits they make.

As a tool for knowledge management, Health technology assessment provides findings that add our knowledge on the relationship between health care interventions and outcomes, and can be used to create and define a range of standards and strategies. Technical characteristics, safety, performance, clinical effectiveness, economic aspects, and costs and structural issues (cultural, social and ethical) are studied in the evaluation of health technology, applications, and technology [14, 3, 15, 2].

The statistics on the medical technologies transfer approaches, provided by the World Health Organization (WHO), show the increased use of the "transfer by the facilitators' support" approach in 2003. This trend has associated with ups and downs, and has had a stable position among the technology transfer methods in the post-2008 years [45].

Several models have been proposed for technology adoption in recent decades including The Task Technology Fit (TTF) Model, Technology Acceptance Model (TAM), and the Unified Theory of Acceptance and Use of Technology (UTAUT) model as the most important ones [44, 41].

5. Summing up the Technology Transfer Risk Assessment Factors

The following items are identified as the risks of technology transfer from a set of studies of theoretical foundations and past research backgrounds:

***Table 1**. Identified risks in technology transfer.*

row	Risk name	row	Risk name	row	Risk name
1	Known change	54	Lack of basic technology to deploy the new technology	108	Lack of legal security of technology intellectual property
2	unforeseen change	55	Lack of proper trade rules	109	Lack of optimization of laws tailored to the needs of the industry
3	Risk of repeated production	56	Lack of infrastructure and technological capabilities	110	Lack of optimization of patent laws
4	The risk of microbial contamination	57	Lack of education tailored to the needs of the industry	111	Lack of a uniform legal structure on the international level
5	The risk of operator error	58	Not to select among the local specialists	112	The intended technology incompatibility with the environment
6	Risk of equipment, possibilities and facilities (technical)	59	lack of inclusive training of all involved personnel	113	Inappropriate political space
7	Delay in project scheduling	60	Failure to create teamwork culture in the organization	114	Modeling risk from other countries
8	Lack of proper planning	61	Inability to communicate effectively between the two organizations	115	Disproportion of the transfer model with sanctioning conditions
9	Lack of supply of raw materials	62	lack of effective communication between the two organizations	116	Lack of a stimulating and appropriate market in the industry
10	Geographical location	63	lack of previous acquaintance between two organizations	117	Type of international relations of the country
11	Transition costs	64	Culture (lack of cultural similarities between the two organizations)	118	The dim role of specialized organizations and advice in helping the IT department
12	Social risks	65	Inability to market the intended technology	119	Not using the experience of consulting organizations to help in technology handling
13	Political risks	66	Not attracting expert people	120	The dim role of the relevant industry development headquarters in conducting research
14	Economic risks	67	Inability to win the trust of industrial contractors	121	The physical environment
15	Personal barriers	68	Unjustified transfer model in terms of organization members	122	Intellectual property Rights
16	Management Attitude	69	lack of communication with suppliers	123	licensing fees
17	Resistance to change	70	organization inability to repair and maintain the equipment required in the technology	124	The weakness of technology management
18	Lack of time	71	Inability to manage and upgrade technology	125	The weakness of the educational system
19	Fulfilling the needs by current products	72	Lack of proper capacity building in the organization (human capacity, hardware, etc.)	126	Technological factors
20	Lack of availability of workforce and resources	73	Failure to create and develop a research unit	127	Lack of localization
21	Resource wasted in imported technologies	74	Failure to choose the transmission model according to the type of tech-	128	transfer environment

row	Risk name	row	Risk name	row	Risk name
			nology		
22	Complexity	75	Failure to achieve new developments after the transfer	129	Nature of technology
23	Disproportionate technology	76	Lack of experience such as technical implicit knowledge in the project to introduce a new technology (lack of basic technical knowledge)	130	Technology transfer process
24	The neutral role of small and medium enterprises	77	Failure to recognize the underlying industrial problems	131	The receiver
25	Inadequate and inefficient internal R & D activities	78	Inability to transform theoretical knowledge into practical knowledge	132	Source of technology
26	Shortage of personnel and excessive workload	79	Management lack of familiarity with transfer models	133	Appropriate technology and target market
27	Lack of adequate support from the executive unit and management	80	The weakness in the ability to localize the transmission model with the native and local conditions of the recipient organization	134	No need for imported technology
28	Unrealistic budget and plan	81	Failure to document the transfer process for optimal use in later transfers	135	Insecurity
29	Ambiguity in the work process and implementation instructions	82	Failure to determine the status of technology in its life cycle	136	Lack of recognition of side effects
30	A work environment that is easily disturbed and the possibility of intervention is high (it is difficult to pay attention to work)	83	Lack of previous experience in this field	137	Increased medical costs
31	A work environment in which there is no sense of cooperation	84	Lack of an appropriate timed schedule	138	Increase inflation
32	Lack of sufficient knowledge on the introduced technology	85	Lack of alignment of the transfer model with organizational goals and strategy	139	Need additional resources, after the arrival of technology
33	Lack of understanding of systems in which new technology is used	86	Non-research-centered organization	140	Scarcity of resources in the health sector
34	Lack of information and business goals	87	Lack of knowledge-based nature of the organization's	141	The moral consequences of using a technology (ignoring individuals, norms, beliefs and decisions about using or not using a technology)
35	Failure to establish proper communications between related companies or between sectors	88	Disproportionate organizational structure with the transfer model	142	shortcoming in expression of the dangers of using a technology
36	Wrong design or errors	89	Lack of right environment for creating new ideas	143	Resources waste due to the lack of distribution of health services based on culture
37	Immaturity and the growth of operations due to the lack of sufficient experience in new technologies	90	Failure to create a dynamic organizational structure	144	Differences in care needs
38	Poor profile of requirements (unspecified requirements)	91	Inability to receive low interest loans	145	Economic conditions

row	Risk name	row	Risk name	row	Risk name
39	Weakness in delivery	92	Lack of strong financial backing of the organization	146	Health system features
40	Delay in delivery	93	Failure to increase market share	147	Less than optimum use of technology
41	Lack of sufficient information of the project	94	Inability to increase profits and returns	148	Potential inequalities in patient access to technology
42	The potential risk of the lack of new technology	95	Inability to improve the organization's capabilities	149	Unnecessary expenses
43	Insufficient New Technology Verification System	96	Lack of proper culture in organization	150	Increase pollution and the Earth's climate change
44	Impact of Interventional systems considering the new technology	97	Lack of power and risk management	151	Lack of financial support
45	influencing certifications (uncertainty of receiving a license)	98	lack of influential people in the organization	152	lack of effectiveness of technology transfer
46	Practical limitations such as availability of equipment	99	Lack of industry trust towards organization	153	Failure to complete the technology transfer phases
47	Providing equipment from suppliers without enough experience in the industry	100	Failure to reward employees appropriately	154	Failure to use technology transfer method
48	Reduce requirements due to practical equipment limitations (due to top level pressure from project failure)	101	Lack of realistic estimation of transfer costs	155	Health effects (effects on health outcomes include mortality, morbidity, quality of life)
49	Escape from responsibility, resulting from inadequate compensation in comparison to high work risk	102	The role of the government in creating demand elasticity in the desired technology	156	Burden of burden (affecting population, common health problems, along with economic / social / health outcomes)
50	Errors or mistakes that arise through excessive or negligent self-confidence	103	Lack of government financial support	157	Cost implications (short-term and long-term effects on the health system, patients, and wider public sector)
51	Lack of employee commitment and lots of changes in contributors	104	lack of government support for domestic research and production	158	Ethical and social consequences (equality, fairness and access)
52	Stress	105	The Impact of Government Change and its Strategies on Technology Transfer	159	Clinical and Policy Importance (Paying attention to clinical practice to reduce disputes, paying attention to policy priorities)
53	Lack of communication and information management system and information technology empowerment	106	Not granting more independence to the organization by the government	160	Feasibility assessment (availability of relevant evidence, time and resources needed to complete evaluation)
				161	Degree of innovation (the new technology scope, with or without therapeutic alternatives)

6. Materials and Methods

The present study is an applied-research in terms of purpose, and a mixed quantitative and qualitative research in terms of the method. In this regard, the Fuzzy AHP method has been used to identify and prioritize the technology transfer risk. The research question can be raised as follows:

What are the components of technology transfer risk assessment in the pharmaceutical-food supplements industry?

The statistical population of this study is consisted of about 50 experts, active in the field of producing or importing animals' pharmaceutical-food supplements. A number of eleven questionnaires were used to conduct statistical analysis on this population. The questionnaire was carried out by self-report method referring directly to sample respondents.

For the purpose of the research, the opinions of some of the professors of the pharmaceutical-food supplements were asked to determine the validity of the questionnaires, and these people expressed their opinions after the study of questionnaires. Finally, the questionnaires were again corrected based on their comments. Cronbach's alpha coefficient was used to verify the reliability of the questionnaires, and reliability is obtained by calculating the incompatibility ratio of the paired matrix matrices for the first questionnaire like all pairwise comparison-based methods. In case that the inconsistency ratio is more than 0.1, the matrix is incompatible and is excluded from the list.

Fuzzy AHP[1] Method

The analytical hierarchy process is one of the most comprehensive approaches designed for multi-criteria decision-making, developed by an Iraqi researcher named Thomas Saaty in the 1970s. This method provides the possibility of formulating the problem in a hierarchical manner, as well as considering different quantitative and qualitative criteria in the problem. It also allows different alternatives in decision making and has the ability of deploying sensitivity analysis on the criteria and sub-criteria [33].

The steps determined by Chang's method are presented in the following: [36].

Step 1: Defining attributes and the main sub-attributes: at the first stage, the main purpose of the problem of assessing the technology transfer risks is defined. The first level in a hierarchy represents the overall goal of the decision problem. The elements affecting the decision making are called criteria and (if necessary) can be divided into sub-criteria. The criteria can be objective or subjective in terms of measuring the contribution of subcomponents in the hierarchy. These criteria are also incompatible, and their priority or relative importance does not depend on the elements of their lower level in the hierarchy. The lowest level includes decision alternatives [29].

Step2: Defining the Fuzzy Numbers: a degree of selection (superiority) from "the equal preference" to "perfectly preferred" is considered for each of the alternatives to convert the designed pairwise matrices to fuzzy numbers, that the fuzzy numbers corresponding to each of them can be seen in the table below.

Table 2. *The corresponding linguistic variables and fuzzy numbers of the Fuzzy AHP process algorithm analyzed by Chang Development Analysis.*

Linguistic variables	Simple Preferred Value	Corresponding fuzzy value
The equal preference	1	(1 1 1)
Interstitial	2	(1.2 3.4 1)
Slightly preferred	3	(2.3 1 3.2)
Interstitial	4	(1 3.2 2)
Relatively preferred	5	(3.2 2 5.2)
Interstitial	6	(2 5.2 3)
Much more preferred	7	(5.2 3 7.2)
Interstitial	8	(3 7.2 4)
Absolutely preferred	9	(7.2 4 9.2)

It should be noted that given the use of linguistic variables and ambiguity in the definition boundary of these variables in the present study, the experts and practitioners are allowed to select a middle variable if they do not distinguish between for example two alternatives of "slightly better" and "relatively better" variables.

Step 3: Forming the pairwise comparisons matrix using fuzzy numbers: The elements in each group are compared in terms of their significance for elements in the upper levels. Comparison of the importance of the main attributes, sub-attributes and alternatives is done with the help of a questionnaire. The questionnaire facilitates the answer to the paired comparison questions. Initially, the experts compared the main attributes to the main goal and then, sub-attributes to the main attributes.

Square matrices, also called priority matrices, are created in the process of comparing elements in each level starting from the top of the hierarchy and moving downwards. The combined weights of the decision alternatives are determined by the sum of the weights in the hierarchy after creating these matrices. This summation is followed by a hierarchy of top-down paths, for each option at the lowest level and multiplied by the weight of each option [29]. At this stage, the number of available questions is considered proportional to the number of elements to be compared by the rule in each section of the paired comparison tables of the questionnaire. That is, if the number of elements to be compared is n, $\frac{n(n-1)}{2}$ will be included in the table. A pairwise matrix is created using the answers of the comparisons between components. In this regard, all the elements in a set are inserted vertically to the left and horizontally above the matrix, and then the resulting numbers are written in the related place. It should be noted that the number inserted in each number of the matrix indicates the preference degree of the row element corre-

1 Analytical Hierarchy Process

sponding to that of the matrix, to the column element. Because each element has a value equal to itself, the original diameter of this matrix will naturally be the number one. In addition, each element will be reversed considering its symmetric element relative to its original diameter, i.e.:

$$a_{ij} = \frac{1}{a_{ji}} \quad (1)$$

Where a_{ij}, is the preference degree of the i-th option or item than the j-th option or item. The data collection step ends by completion of the paired comparison matrix derived from the above tables.

Step 4: Integrating the pairwise comparison matrix: the analytical hierarchy method utilizes geometric average for combining the comparative tables of all the respondents with each other. The mathematically best mean represents the geometric mean since pairwise comparisons are made in the form of the "ratio".

The group pairwise comparison matrix elements are calculated as follows in group decision making based on the hierarchical analysis method, used in this study:

$$\left(\prod_{k=1}^{N} a_{ij}{}^{(k)}\right)^{\frac{1}{N}} = a_{ij}{}^{(k)}\ a_{ij} \quad (2)$$

Where n is the number of decision makers, $a_{ij}{}^{(k)}$ is the component related to the k-th person for comparing the i-th factor to the j-th factor and a_{ij} is also the geometric mean of all the opinions about the preference of the i-th factor than the j factor.

Step5: calculations to find the Compatibility Index (CI), Compatibility Rate (CR): Matrix compatibility should be considered in implementing the pairwise comparison matrix. The matrix $A = [a_{ij}]$ is said to be compatible if $a_{ik} \times a_{kj} = a_{ij}$. The degree of incompatibility less than 0.1 is acceptable in pairwise comparison matrices. In cases where the pairwise matrix is related to fuzzy numbers, first, the numbers of this matrix turn fuzzy, and then the incompatibility ratio is calculated for these matrices. If the inconsistency coefficient is satisfactory, then the decision is made based on normalized values; otherwise, this procedure will be repeated as long as these values are within the desired range [40].

Consistency check steps

Dividing the fuzzy triangular matrix into two matrices below:

The middle numbers of the triangular trials $A^m = [a_{ijm}]$ and the geometric mean of the upper and lower bounds of the triangular numbers $A^g = \sqrt{a_{iju}.a_{ijl}}$.

Calculate the weight vector of each matrix using the Saaty method:

$$\begin{cases} w^m = [w_i{}^m]\ w_i{}^m = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ijm}}{\sum_{i=1}^{n} a_{ijm}} \\ w^g = [w_i{}^g]\ w_i{}^g = \frac{1}{n}\sum_{j=1}^{n}\frac{\sqrt{a_{iju}.a_{ijl}}}{\sum_{i=1}^{n}\sqrt{a_{iju}.a_{ijl}}} \end{cases} \quad (3)$$

Calculating the largest Eigen Value for each matrix:

$$\begin{cases} \lambda_{max}^{m} = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ijm}\left(\frac{w_j{}^m}{w_i{}^m}\right) \\ \lambda_{max}^{g} = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n}\sqrt{a_{iju}.a_{ijl}}\left(\frac{w_j{}^g}{w_i{}^g}\right) \end{cases} \quad (4)$$

Calculating the compatibility index using the following relationships:

$$\begin{cases} CI^m = \frac{(\lambda_{max}^{m} - n)}{n-1} \\ CI^g = \frac{(\lambda_{max}^{g} - n)}{n-1} \end{cases} \quad (5)$$

Calculating Inconsistency Rate (CR):

$$\begin{cases} CR^m = \frac{CI^m}{RI^m} \\ CR^g = \frac{CI^g}{RI^g} \end{cases} \quad (6)$$

Table 3. *Random index.*

N	1	2	3	4	5	6	7	8	9	10
R	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

The fuzzy matrix is consistent if both of these indicators are less than 0.1. If both are more than 0.1, the decision maker is required to revisit the priorities, and if $CR^m(CR^g)$ is greater than 0.1, the decision maker will reconsider the average values (limits) of fuzzy judgments [46].

Step 6: Calculating the sum of the elements of the rows and the magnitude of the Ss than each other in the decision matrix: let assume i represents the row number and j denotes the column number in the decision matrix, and a_{ij} represents each of the elements of the decision matrix with the fuzzy triangle number. In this case, the sum of the rows elements is obtained as follows:

$$\tilde{S}_i = \sum_{j=1}^{n}\tilde{a}_{ij} \quad i = 1,2,3,\dots,n \quad (7)$$

At this stage, the degree of probability that each μ_i being larger than other μ_is, known as $d'A_i$, will be determined:

$$d'(A_i) = MinV(M_i \geq M_k)\ k = 1,2,3,\dots,n\ k \neq i \quad (8)$$

Step 7: normalization and calculation of the weight vector of the criteria and sub-criteria: Finally, we obtain the normalization weights by normalizing the weight vector (w'), and obtain the final weight by combining the weights and alternatives [36].

$$w = \left[\frac{d'(A_1)}{\sum_{i=1}^{n} d'(A_i)}, \frac{d'(A_2)}{\sum_{i=1}^{n} d'(A_i)}, \dots, \frac{d'(A_n)}{\sum_{i=1}^{n} d'(A_i)}\right] \quad (9)$$

For the purpose of normalization, we divide each row by the rows sum.

Step 8: Final ranking: the final weight of each option is obtained by multiplying the weights of the corresponding criteria, and the criteria and attributes will be prioritized [34].

7. The Model Results

7.1. Identifying the Key Attributes for the Technology Transfer Risk Assessment in the Pharmaceutical-food Supplement Industry

Table 4*. Summary of the results of the factors affecting the selection of key attributes of Technology Transfer risk assessment in the pharmaceutical-food supplement industry.*

row	The main criterion	Technology transfer risks	Average	Standard deviation	t Test Value = 3	df	Sig. (2-tailed)	Mean Difference	Indicator Quality
1	influence on health	The risk of microbial contamination	4.0192	0.82819	8.875	51	0	10.01923	OK
2		medicine side effects	4.1923	0.84107	10.223	51	0	10.19231	OK
3		The short-term and long-term effects on the health system	3.9038	0.89134	7.312	51	0	0.90385	OK
4	Resources accessibility	Incompleteness of technology supply chain and the lack of proper suppliers	3.9808	0.7794	9.074	51	0	0.98077	OK
5		organization inability to repair and maintain the equipment required in the intended technology	3.7308	0.9521	5.535	51	0	0.73077	OK
6		The problems with funding needed to transfer	4.0385	0.92803	8.069	51	0	10.03846	OK
7		Limited access to equipment and facilities due to sanctions or other reason.	4.0192	0.85154	8.631	51	0	10.01923	OK
8		Failure to supply the necessary raw materials to conduct the project	3.7500	0.94713	5.71	51	0	0.75	OK
9		Lack of availability of specialist workforce	3.7308	10.08674	4.849	51	0	0.73077	OK
10		lack of new technology verification systems	3.7308	0.81926	6.432	51	0	0.73077	OK
11	Organizational Management and leadership Capability	Lack of education in accordance with technology	3.9808	0.89641	7.89	51	0	0.98077	OK
12		Delay in project scheduling	3.5769	0.89325	4.657	51	0	0.57692	OK
13		Inability to market new products	3.6731	10.00433	4.833	51	0	0.67308	OK
14		Lack of proper capacity building in the organization (human capacity, hardware,	3.4423	0.97846	3.26	51	0.002	0.44231	OK

row	The main criterion	Technology transfer risks	Average	Standard deviation	t Test Value = 3	df	Sig. (2-tailed)	Mean Difference	Indicator Quality
		etc.)							
15		Lack of experience and tacit knowledge for the project	3.8462	0.8491	7.186	51	0	0.84615	OK
16		Failure to document the transfer process for optimal use in upcoming technology transfer projects	3.6346	0.92945	4.924	51	0	0.63462	OK
17		Lack of alignment between the transfer model with organization goals and strategy	3.5962	10.01479	4.236	51	0	0.59615	OK
18		Disproportion of organizational structure with the transfer model	3.5385	0.9174	4.232	51	0	0.53846	OK
19		Inability to manage and upgrade technology	3.8654	0.88625	7.041	51	0	0.86538	OK
20		technology incompatibility with the environment	3.5385	10.16251	3.34	51	0.002	0.53846	OK
21		HSE problems	3.5962	0.93431	4.601	51	0	0.59615	OK
22		Failure to achieve new developments after the transfer	3.6731	0.92294	5.259	51	0	0.67308	OK
23		The technology complexity	3.9423	0.87253	7.788	51	0	0.94231	OK
24		Inadequate and inefficient internal R&D activities	3.8462	0.77674	7.856	51	0	0.84615	OK
25	The essence of technology and its nature	Lack of technical know-how in the field of the introduced technology	3.9231	0.8822	7.545	51	0	0.92308	OK
26		Immaturity and the growth of operations due to the lack of experience of new technologies	3.6538	0.7379	6.39	51	0	0.65385	OK
27		Immaturity of technology	3.7692	0.73071	7.591	51	0	0.76923	OK
28		Lack of basic technology to deploy the new technology	3.8654	0.84084	7.422	51	0	0.86538	OK
29		Little knowledge of the company and industry on new technology	3.8462	0.82568	7.39	51	0	0.84615	OK
30		Changes in business rules	3.5962	10.01479	4.236	51	0	0.59615	OK
31		Lack of realistic estimation of transfer costs	3.7692	0.73071	7.591	51	0	0.76923	OK
32	dependence on government policy and socioeconomic problems	Change of government and its strategies	3.8269	0.83363	7.153	51	0	0.82692	OK
33		Lack of legal security of the intellectual property of technology	4.0385	0.83927	8.923	51	0	10.03846	OK
34		Disapproval of the transfer	3.8269	0.7598	7.848	51	0	0.82692	OK

row	The main criterion	Technology transfer risks	Average	Standard deviation	t Test Value = 3	df	Sig. (2-tailed)	Mean Difference	Indicator Quality
		model with sanctioning conditions							
35		Lack of an incentive market in the industry	3.7500	0.83725	6.46	51	0	0.75	OK
36		Increased inflation	3.9423	0.9983	6.807	51	0	0.94231	OK
37		The moral consequences of using technology (ignoring individuals, norms, beliefs and decisions about using or not using a technology)	3.7885	0.91473	6.216	51	0	0.78846	OK

The key attributes of the technology transfer risk assessment are presented in the five groups of criteria frame-work in the pharmaceutical-food supplements industry in the table above. As can be seen in the above table, only 37 items have been remained in the list of key attributes of technology transfer risk assessment in the pharmaceutical-food supplements industry. It should be noted that, in some cases, several attributes are expressed in terms of a single criterion due to their coherent and interconnected nature. These include "the lack of inclusive education of all involved personnel," "the inability to translate theoretical knowledge into practical work" and "lack of education fitted with technology," that all of which were presented as "the lack of appropriate technology education".

7.2. Determining the Importance of Key Attributes of Technology Transfer Risk Assessment in the Pharmaceutical-food Supplements Industries Using Fuzzy Hierarchical Programming Method

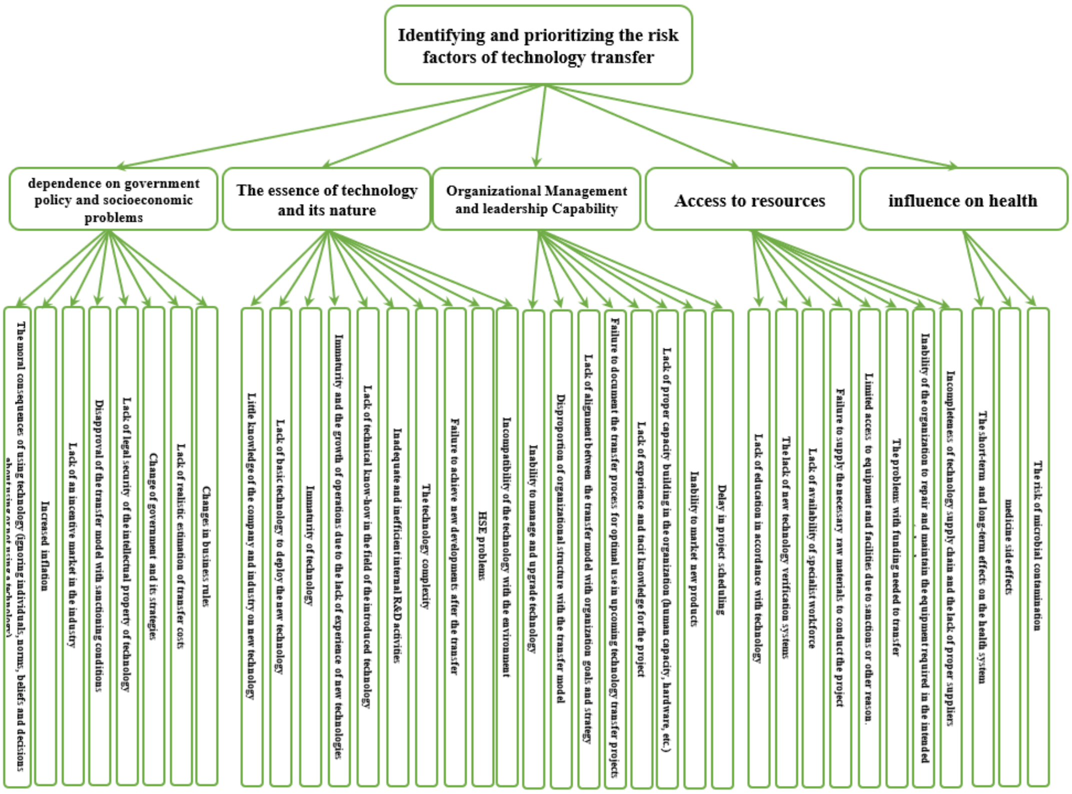

Figure 1. Hierarchical structure process.

Table 5. *Incorporation of the incompatibility rate of main criteria and sub-criteria of Technology Transfer Risks in the pharmaceutical-food supplementary industry.*

	incompatibility rate	
	CR^g	**CR^m**
Main Criteria Matrix	0.03252	0.01774
The sub-criteria matrix of the criterion of "influence on health"	0.06093	0.04429
The sub-criteria matrix of the criterion of "Resources accessibility"	0.05732	0.04662
The sub-criteria matrix of the criterion of "Organizational Management and leadership Capability"	0.05531	0.05095
The sub-criteria matrix of the criterion of "The essence of technology and its nature"	0.00767	0.03808
The sub-criteria matrix of the criterion of "dependence on government policy and socioeconomic problems"	0.05606	0.01848

Table 6. *Degree of importance and the weight of the main components of technology transfer.*

Criteria Name	weight	degree of importance
influence on health	0.489	1
Resources accessibility	0.298	0.641
Organizational Management and leadership Capability	0.012	0.015
The essence of technology and its nature	0.18	0.404
dependence on government policy and socioeconomic problems	0.021	0.021

Based on the above table and the Chang Development Analysis Method, it can be concluded that the criterion of "influence on health" (0.489) is considered as the most important alternative, followed by "resources accessibility" (0.298), respectively, in terms of significance in prioritization. It should be noted that the fuzzy AHP method calculations have not been presented for the purpose of brevity.

Table 7. *Degree of importance and weight of the sub-criteria of the main criterion of the "influence on health".*

sub-criteria Name	weight	degree of importance
The risk of microbial contamination	0.755	1
medicine side effects	0.212	0.777
The short-term and long-term effects on the health system	0.023	0.235

According to the above table, the sub-criterion of the risk of microbial contamination (0.775) is the most important sub-criterion in evaluating the main criterion of "influence on health".

Table 8. *Degree of importance and weight of the sub-criteria of the main criterion of the "resources accessibility".*

sub-criteria Name	weight	degree of importance
Incompleteness of technology supply chain and the lack of proper suppliers	0.254	0.903
Inability of the organization to repair and maintain the equipment required in the intended technology	0.102	0.363
The problems with funding needed to transfer	0.282	1
Limited access to equipment and facilities due to sanctions or other reason.	0.179	0.643
Failure to supply the necessary raw materials to conduct the project	0.153	0.551
Lack of availability of specialist workforce	0.005	0.018
Lack of new technology verification systems	0.016	0.014
Lack of education in accordance with technology	0.009	0.008

As can be seen in the above table, the sub-criteria of "the problems of funding needed for transfer" (0.282), "The incompleteness of the technology supply chain and the lack of suitable suppliers" (0.254), and "limited access to equipment and facilities due to sanctions and other reasons" (0.179), are the most important sub-criteria in evaluating the main criterion of "resources accessibility ".

Table 9. *Degree of importance and weight of the sub-criteria of the main criterion of the "Organizational Management and leadership Capability".*

sub-criteria Name	weight	degree of importance
Delay in project scheduling	0.265	1
Inability to market new products	0.106	0.419
Lack of proper capacity building in the organization (human capacity, hardware, etc.)	0.261	0.968
Lack of experience and tacit knowledge for the project	0.152	0.564
Failure to document the transfer process for optimal use in upcoming technology transfer projects	0.168	0.624
Lack of alignment between the transfer model with organization goals and strategy	0.027	0.136
Disproportion of organizational structure with the transfer model	0.017	0.103
Inability to manage and upgrade technology	0.004	0.065

According to the above table, the sub-criteria of "delay in project scheduling" (0.265), "the lack of proper capacity in the organization such as human capacity, hardware etc."(0.261), and "inability to document the transfer process for optimal use in future technology transfer projects "(0.168), are the most important sub-criteria of the main criterion of "organizational management and leadership capability".

Table 10. *Degree of importance and weight of the sub-criteria of the main criterion of the "The essence of technology and its nature".*

sub-criteria Name	weight	degree of importance
technology incompatibility with the environment	0.28	1
HSE problems	0.066	0.272

sub-criteria Name	weight	degree of importance
Failure to achieve new developments after the transfer	0.185	0.66
The technology complexity	0.224	0.801
Inadequate and inefficient internal R&D activities	0.082	0.327
Lack of technical know-how in the field of the introduced technology	0.101	0.361
Immaturity and the growth of operations due to the lack of experience of new technologies	0.028	0.099
Immaturity of technology	0.014	0.054
Lack of basic technology to deploy the new technology	0.011	0.036
Little knowledge of the company and industry on new technology	0.009	0.024

As can be seen in the above table, the sub-criteria of "the lack of compatibility of the desired technology with the environment"(0.280), "the technology complexity" (0.224), "the lack of possibility of achieving new developments after the transfer"(0.185) and "the lack of know-how in the field of introduced technology" (0.101), are the most important sub-criteria for the main criterion of "the essence of technology and its nature".

Table 11. *Degree of importance and weight of the sub-criteria of the main criterion of the "dependence on government policy and socioeconomic problems".*

sub-criteria Name	weight	degree of importance
Changes in business rules	0.259	0.825
Lack of realistic estimation of transfer costs	0.164	0.525
Change of government and its strategies	0.35	1
Lack of legal security of the intellectual property of technology	0.07	0.256
Disapproval of the transfer model with sanctioning conditions	0.067	0.247
Lack of an incentive market in the industry	0.046	0.214
Increased inflation	0.028	0.162
The moral consequences of using technology (ignoring individuals, norms, beliefs and decisions about using or not using a technology)	0.016	0.116

According to the above table, the sub-criteria of "change of government and its strategies" (0.350), "changes in business rules" (0.259) and "lack of real estimation of transfer costs" (0.164), are the most important sub-criteria of the main criterion of "dependence on government policy and socio-economic problems".

Table 12. *The final weights of risks affecting the technology transfer in the pharmaceutical-food supplements industry.*

Row	The main criterion	weight	ID	Technology transfer risks	The final weight of the sub-criteria	The weight of sub-criteria
1	influence on health	0.489	X_1	The risk of microbial contamination	0.755	0.3692
2			X_2	Medicine side effects	0.212	0.10367

Row	The main criterion	weight	ID	Technology transfer risks	The final weight of the sub-criteria	The weight of sub-criteria
3			X_3	The short-term and long-term effects on the health system	0.023	0.01125
4			X_4	Incompleteness of technology supply chain and the lack of proper suppliers	0.254	0.07569
5			X_5	The organization inability to repair and maintain the equipment required in the intended technology	0.102	0.0304
6			X_6	The problems with funding needed to transfer	0.282	0.08404
7	resources accessibility	0.298	X_7	Limited access to equipment and facilities due to sanctions or other reason.	0.179	0.05334
8			X_8	Failure to supply the necessary raw materials to conduct the project	0.153	0.04559
9			X_9	Lack of availability of specialist workforce	0.005	0.00149
10			X_{10}	Lack of new technology verification systems	0.016	0.00477
11			X_{11}	Lack of education in accordance with technology	0.009	0.00268
12			X_{12}	Delay in project scheduling	0.265	0.00318
13			X_{13}	Inability to market new products	0.106	0.00127
14			X_{14}	Lack of proper capacity building in the organization (human capacity, hardware, etc.)	0.261	0.00313
15			X_{15}	Lack of experience and tacit knowledge for the project	0.152	0.00182
16	Organizational Management and leadership Capability	0.012	X_{16}	Failure to document the transfer process for optimal use in upcoming technology transfer projects	0.168	0.00202
17			X_{17}	Lack of alignment between the transfer model with organization goals and strategy	0.027	0.00032
18			X_{18}	Disproportion of organizational structure with the transfer model	0.017	0.0002
19			X_{19}	Inability to manage and upgrade technology	0.004	0.00005
20			X_{20}	technology incompatibility with the environment	0.28	0.0504
21			X_{21}	HSE problems	0.066	0.01188
22			X_{22}	Failure to achieve new developments after the transfer	0.185	0.0333
23			X_{23}	The technology complexity	0.224	0.04032
24			X_{24}	Inadequate and inefficient internal R&D activities	0.082	0.01476
25	The essence of technology and its nature	0.18	X_{25}	Lack of technical know-how in the field of the introduced technology	0.101	0.01818
26			X_{26}	Immaturity and the growth of operations due to the lack of experience of new technologies	0.028	0.00504
27			X_{27}	Immaturity of technology	0.014	0.00252
28			X_{28}	Lack of basic technology to deploy the new technology	0.011	0.00198
29			X_{29}	Little knowledge of the company and industry on new technology	0.009	0.00162
30			X_{30}	Changes in business rules	0.259	0.00544
31	dependence on government policy and socioeconomic	0.021	X_{31}	Lack of realistic estimation of transfer costs	0.164	0.00344
32			X_{32}	Change of government and its strategies	0.35	0.00735

Row	The main criterion	weight	ID	Technology transfer risks	The final weight of the sub-criteria	The weight of sub-criteria
33	problems		X_{33}	Lack of legal security of the intellectual property of technology	0.07	0.00147
34			X_{34}	Disapproval of the transfer model with sanctioning conditions	0.067	0.00141
35			X_{35}	Lack of an incentive market in the industry	0.046	0.00097
36			X_{36}	Increased inflation	0.028	0.00059
37			X_{37}	The moral consequences of using technology (ignoring individuals, norms, beliefs and decisions about using or not using a technology)	0.016	0.00034

As shown in the table above, the "influence on health" criterion is the most important criterion with a final weight of 0.489 followed by the "resources accessibility" criterion.

Table 13. *The final ranking of risks affecting the Technology Transfer in the pharmaceutical-food supplementary industries.*

Rank	The weight of sub-criteria	Technology transfer risks
1	0.3692	The risk of microbial contamination
2	0.10367	Medicine side effects
3	0.08404	The problems with funding needed to transfer
4	0.07569	Incompleteness of technology supply chain and the lack of proper suppliers
5	0.05334	Limited access to equipment and facilities due to sanctions or other reason.
6	0.0504	technology incompatibility with the environment
7	0.04559	Failure to supply the necessary raw materials for the project
8	0.04032	technology complexity
9	0.0333	Failure to achieve new developments after transfer
10	0.0304	Inability of the organization to repair and maintain the equipment required in the intended technology
11	0.01818	Lack of technical know-how in the field of the introduced technology
12	0.01476	Inadequate and inefficient internal R&D activities
13	0.01188	HSE problems
14	0.01125	The short-term and long-term effects on the health system
15	0.00735	Change of government and its strategies
16	0.00544	Changes in business rules
17	0.00504	Immaturity and the growth of operations due to the lack of experience of new technologies
18	0.00477	Lack of new technology verification systems
19	0.00344	Lack of realistic estimation of transfer costs
20	0.00318	Delay in project scheduling
21	0.00313	Lack of proper capacity building in the organization (human capacity, hardware, etc.)
22	0.00268	Lack of education in accordance with technology
23	0.00252	Immaturity of technology

Rank	The weight of sub-criteria	Technology transfer risks
24	0.00202	Failure to document the transfer process for optimal use in upcoming technology transfer projects
25	0.00198	Lack of basic technology to deploy the new technology
26	0.00182	Lack of experience and tacit knowledge for the project
27	0.00162	Little knowledge of the company and industry on new technology
28	0.00149	Lack of availability of specialist workforce
29	0.00147	Lack of legal security of the intellectual property of technology
30	0.00141	Disapproval of the transfer model with sanctioning conditions
31	0.00127	Inability to market new products
32	0.00097	Lack of an incentive market in the industry
33	0.00059	Increased inflation
34	0.00034	The moral consequences of using technology (ignoring individuals, norms, beliefs and decisions about using or not using a technology)
35	0.00032	Lack of alignment between the transfer model with organization goals and strategy
36	0.0002	Disproportion of organizational structure with the transfer model
37	0.00005	Inability to manage and upgrade technology

According to the above table, the "risk of microbial contamination" with a final weight of 0.36920 is considered as the most important risk among the technology transfer risks in the pharmaceutical-food supplements industry.

8. The Research Model

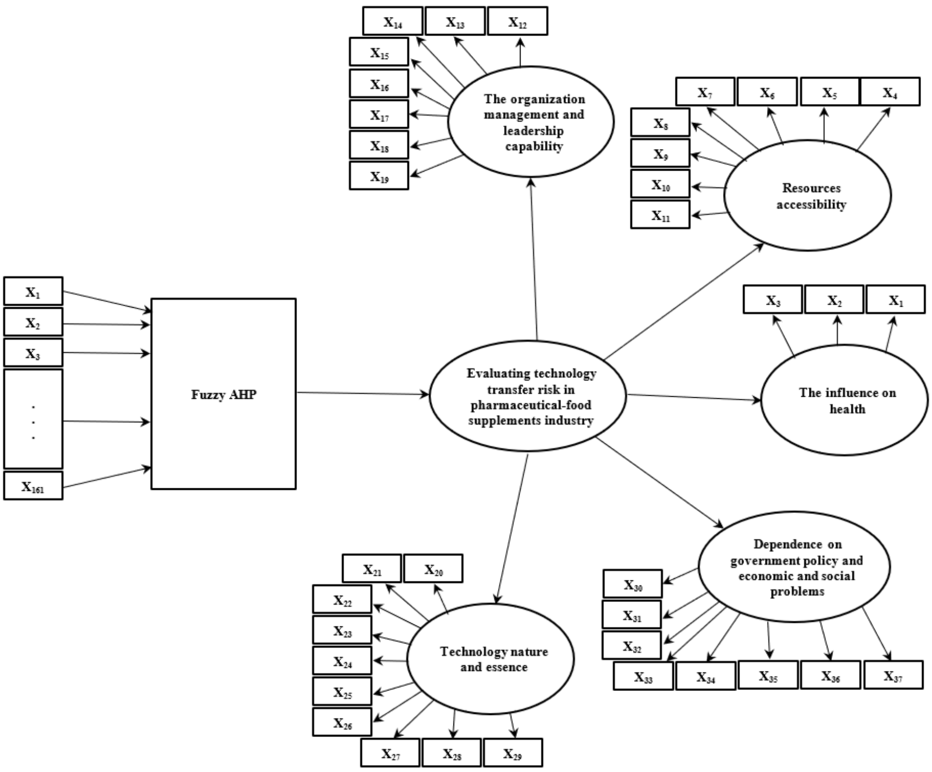

Figure 2. *Criteria prioritization hierarchical model.*

Descriptive and inferential analysis of the research results

The present research was aimed to identify and categorize the components of technology transfer risk assessment in the pharmaceutical-food supplement industry. At the first stage, in order to identify all the risks of technology transfer, the library studies, including books, articles and theses were used which resulted in drawing 161 risks in technology transfer. Then, an interview was conducted with 11 experts in order to gather the experts' initial opinions, to determine the more effective risks in the pharmaceutical-food supplements industry. Necessary adjustments were made according to the experts' comments and content analysis to guarantee the face and content validity, and in this way, a number 37 risks with higher priority were obtained, which classified into five main categories. Finally, the quantitative data gathering process started after ensuring of the reliability of the questionnaire. A total of five main criteria was identified for the technology transfer risks in the pharmaceutical-food supplements industry considering the results obtained from the paired comparisons through fuzzy AHP and determining the weight and significance of the factors, considering the utility of the incompatibility rate for these factors as well as the desirable outcome of the t test for all the items in the questionnaire, including "influence on health" "resources accessibility," "organizational management and leadership capability," "the essence of technology and its nature," and "dependence on government policy and socio-economic problems". After identifying the main criteria for the risk of technology transfer in the pharmaceutical-food supplements industry, obtained criteria were prioritized using the fuzzy AHP methodology. Accordingly, the influence on health criterion, with a normal weight of 0,489, was identified as the most common criterion among the technology transfer risks in the pharmaceutical-food supplements industry and the criterion of "organizational management and leadership capability" had the lowest importance degree with a normal weight of 0.122. One of the limitations, facing the present study, was the lack of pharmaceutical-food supplements-related experts' familiarity with the concept of technology transfer risk.

Research suggestions and recommendations

Studying the application of artificial intelligence in identifying and assessing the risk of technology transfer in the pharmaceutical-food supplements industry;

Implementing the following strategies, based on the priority of the corresponding risks, to reduce the risk of technology transfer:

Table 14. *The solutions to reduce the risks of Technology Transfer in the pharmaceutical-food supplements industry (source: research findings).*

Main risks identified in the research	Risk Reduction Strategies
The risk of microbial contamination	All stages of production and maintenance of materials and machinery should be away from moisture.
	Defining and implementing a standard for the products quality control (such as the US FDA).
The medication side effects	Enhancing nutritional literacy of people;
	Investigating that whether there is an inherent need for complementary foods depending on the type of nutrition and food behavior.
The problems of funding needed to transfer	Evaluating the importance of the intended technology entry.
	Pharmacoeconomic enhancement in the pharmaceutical-food projects analysis
Incompleteness of the technology supply chain and the lack of suppliers	Reinforcing the most popular brands in the pharmaceutical-food supplements industry
Limited access to equipment and facilities due to sanctions and other reasons	Investigating the possibility to use similar machines and devices, verified by the main representatives of the products, in the country;
	Investigating the extent to which the raw materials can be produced internally

Abbreviations

AHP	Analytic Hierarchy Process
HTA	Health Technology Assessment
INAHTA	International Network of Agencies for Health Technology Assessment
WHO	World-Health-Organization
TTF	Task Technology Fit
TAM	Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology
FDA	Food and Drug Administration

Conflicts of Interest

The authors declare no conflicts of interest.

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