Food and Nutrition Security in Iran: Application of TOPSIS Technique

ZAHRA ARDAKANI*, FABIO BARTOLINI*, GIANLUCA BRUNORI*

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Abstract

Food and nutrition security is a multi-dimensional subject. The definition of the FAO in 1996, i.e. "when all people at all times have access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life", presents the following four core dimensions. It includes: a) physical availability of food, b) economic and physical access to food, c) food utilization, and d) stability of the other three dimensions. Consequently, achieving food and nutrition security, as the main goal of food systems, requires adequate Food Availability, Food Accessibility, Food Utilization and Food Stability. The pathway to food and nutrition security begins by exploring the challenges, whose knowledge is needed for developing adequate solutions. Thus, decision-making is the process of discovering the best decision from all of the possible alternatives. Multi-Criteria Decision-Making Models have received much consideration from researchers as a tool to assess and rank alternatives. Amongst various multi-criteria decision-making models, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) remains to work adequately. The major focus of the paper is to provide a synthesizing judgment about the Food and Nutrition Security (FNS) performance, including multiple and conflict criteria. We apply TOPSIS technique as a multi-criteria method, to build a dynamic quantitative national-level food and nutrition security index to be used as a benchmark for all dimensions of food and nutrition security, and prioritize the vulnerabilities of food system in the delivery of food and nutrition security in Iran. Using this technique, we survey how the food system has worked to provide food and nutrition security over time, in order to check if it has improved or worsened. We also analyze the level of overall vulnerability of food system by investigating changes in the four dimensions of food and nutrition security over the time in Iran.

***Keywords**: Food and Nutrition Security, TOPSIS Technique, Indicators, Iran.*

Résumé

La sécurité alimentaire et nutritionnelle est une question multidimensionnelle. Comme il a été reconnu lors du Sommet de la FAO en 1996, elle existe « lorsque tous les êtres humains ont, à tout moment, accès à une nourriture suffisante, saine et nutritive leur permettant de satisfaire leurs besoins énergétiques et leurs préférences alimentaires pour mener une vie saine et active ». Cette définition englobe quatre dimensions principales : la disponibilité physique de la nourriture, l'accès économique et physique à la nourriture, l'utilisation de la nourriture et la stabilité. Par conséquent, si atteindre une sécurité alimentaire et nutritionnelle reste l'objectif principal des systèmes alimentaires, il est nécessaire d'assurer une disponibilité alimentaire, une accessibilité alimentaire, une utilisation alimentaire et une stabilité alimentaire appropriées. Le parcours vers la sécurité alimentaire et nutritionnelle sera engagé en explorant les défis qu'il faut appréhender pour développer des solutions adéquates. Ainsi, le processus de prise de décision consistera à découvrir les meilleures décisions à partir de toutes les alternatives possibles. Les modèles d'aide à la décision multicritère ont reçu une grande attention de la part des chercheurs qui les considèrent comme un outil pour évaluer et classer les alternatives possibles. Parmi les différentes approches d'aide à la décision multicritère, la méthode TOPSIS (*Technique for Order Preference by Similarity to Ideal Solution*) s'avère bien adaptée. Le but de ce travail est d'évaluer synthétiquement la performance de la sécurité alimentaire et nutritionnelle, en intégrant des critères multiples et conflictuels. Nous allons adopter la méthode TOPSIS comme un modèle multicritère pour construire un indicateur de sécurité alimentaire et nutritionnelle dynamique, quantitatif et à l'échelle nationale qui servira de référence pour toutes les dimensions de la sécurité alimentaire et nutritionnelle, et pour hiérarchiser les vulnérabilités du système alimentaire dans l'assurance de la sécurité alimentaire et nutritionnelle en Iran. En nous appuyant sur cette méthode, nous allons examiner le fonctionnement du système alimentaire au fil du temps eu égard à la sécurité alimentaire et nutritionnelle, afin de déterminer sa progression ou sa régression. Par ailleurs, nous allons analyser le niveau de vulnérabilité générale du système alimentaire en examinant l'évolution dans le temps des quatre dimensions de la sécurité alimentaire et nutritionnelle en Iran.

Mots-clé : Sécurité alimentaire et nutritionnelle, méthode TOPSIS, indicateurs, Iran.

1. Introduction

One of the challenges of food and nutrition security is the capacity of food systems to achieve their goals, even in the face of multiple and unpredictable drivers of change (Tendall *et al*., 2015). Food systems contain a set of actions going from production to consumption that include both human and environment dimensions. Once a food system cannot deliver food and nutrition security or does not have the potential to do so, the system is considered vulnerable to one or more stresses (Ericksen, 2008). Reducing food systems vulnerability to sudden shocks and long-term stress contributes to achieving food and nutrition security (Berardi *et al*., 2011). Food and nutrition security is the main goal of food systems (Ericksen, 2008).

The World Food Summit held in Rome in 1996 and 2002, and the Millennium Development Goals, all emphasize the importance of food and nutrition security. The responsibility to eliminate food and nutrition insecurity rests on a number of public and non-public institutes that need to take proper actions since around 800 million people in developing, and 34 million in developed countries are undernourished. Due to rising world population, this situation may even worsen unless effective and well-targeted actions are taken to improve food and nutrition security (FAO, 2003).

Several challenges influence whether an individual, household or community reaches and maintains food and nutrition security. Social and economic status, climate change and population growth are some of the factors that could negatively affect availability, accessibility and utilization of nutritious food across all populations. These factors are a serious threat and they need a careful consideration within the post-2015 food and nutrition security agenda (Fanzo, 2014).

Improving food and nutrition security needs many components. The definition of food and nutrition security by FAO is identified and agreed. As we have previously stated, there are four dimensions in food and nutrition security: availability, access, utilization and stability (Hanie *et al*., 2013). Food availability is related to the supply side of food and

* Department of Agricultural, Food and Environmental Economics, University of Pisa, Pisa, Italy. Corresponding author: zahra.ardakani@gmail.com

nutrition security and specified by the level of food production, stock levels and net trade. Market factors and the price of food as well as the purchasing power of individuals that is related to employment and livelihood opportunities, influence access to food. Food utilization regards the way that body receives the most of main nutrients in the food and it is related to the health of people. Finally yet importantly, the stability dimension of food and nutrition security underlines the importance of reducing the risk of negative effects on the other dimensions (FAO, 1996).

Policy-makers are usually the end users of research results. They need visions about how different situations will affect food and nutrition security. The widely varying results of different research works, limited number of drivers included in models and the lack of transparency in reporting, are not truly helpful in supporting policy-makers. Researchers have to make a greater effort to support policy-makers in making policy decisions and in selecting the best one among several alternatives (Dijk and Meijerink, 2014).

The literature to date focuses on various dimensions of food and nutrition security when establishing an observational connection between consequences and prior interventions. Nevertheless, since food and nutrition security is characterized by multiple dimensions, and it can be defined at the national, local, household or the individual level, the combination of indicators seems to be the most useful strategy to assess the state of food and nutrition security of a country (Bartelli and Macours, 2014). The analysis of food and nutrition security needs to be conducted (Lacirignola, 2015). Developing countries require to invest in agriculture, public and private, to achieve food and nutrition security (Branca *et al*., 2015).

Iran, with a population of approximately 77 million people and estimated populations of around 88 and 100 million in 2025 and 2050, respectively, is the second largest country in the Middle East after Saudi Arabia and ranked as an upper-middle income developing country among the World Bank states (Heslot, 2014; Emami *et al*., 2015). Agriculture sector, the main sector in producing food, is very inefficient in Iran and faces several difficulties (Heslot, 2014) in the production and marketing system (Ardakani *et al*., 2009). Soil salinity, water scarcity, dry climatic conditions and the outdated methods and equipment limit the ability of the production system in producing food in Iran (Heslot, 2014). Similar to the other developing countries, around one-third of food is lost and wasted during the food supply chains (HLPE, 2014) in Iran, which can show inefficiency in the marketing system in the country. Based on the existing statistics, an average of 35 percent of agricultural products is lost and wasted in Iran and this amount of products would feed 15 to 20 million people (Pirmoradi *et al*., 2013). Economic factors appear to affect the food system in Iran to be vulnerable in achieving food and nutrition security. High unemployment rate, high inflation rate and high exchange rate have reduced purchasing power of Iranians to buy enough and safe food (Heslot, 2014; HLPE, 2014; Mohammadi-Nasrabadi *et al*., 2014; Emami *et al*., 2015). In recent years, several studies have reported that food and nutrition insecurity has occurred in Iran (Behzadifar *et al*., 2016; Hamedi Shahraki *et al*., 2016). The prevalence of food and nutrition insecurity has been calculated to be high (Behzadifar *et al*., 2016) among diverse groups of people. Behzadifar *et al*. in 2016 have calculated the prevalence of food and nutrition insecurity as follows: 49 percent among households, 67 percent in children, 61 percent in mothers, 49 percent in adolescents and 65 percent in the elderly. In addition, a nutrition change is also happening in Iran. Consumption of the traditional diet that is based on wheat, fruits and vegetables has declined and changed to have more sugar, oil and fat. The dietary changes have caused widespread micronutrient deficiencies particularly iodine and iron (Heslot, 2014).

Evidence show that Iran faces a number of issues that threaten its food and nutrition security. Iran has not been studied yet in the international academic literature on food and nutrition security. The EIU Global Food Security Index provides a worldwide perspective on the countries that are the most and least vulnerable to food and nutrition insecurity; it considers three core issues of affordability, availability, and quality across a set of 109 countries. However, this index is not available for Iran.

Therefore, in this paper, we provide a brief evaluation of the Food and Nutrition Security (FNS) performance including multiple and conflicting criteria. Using TOPSIS technique as a multi-criteria method, we have built a dynamic quantitative national-level food and nutrition security index to benchmark all indicators and dimensions of food and nutrition security in order to find out the vulnerabilities in the food system delivering food and nutrition security in Iran. We have surveyed how the food system has worked to provide food and nutrition security over time, in order to evaluate if it has improved or worsened. As well, we have analyzed the level of overall vulnerability of a food system by investigating changes in the four dimensions of food and nutrition security over the time in Iran. Whereas an indicator is defined as a variable that quantifies and characterizes the level of vulnerability or resilience in a country (Krishnamurthy *et al*., 2014), using this method, we have built a composite index to summarize the overall vulnerability or resilience to external and internal impacts.

This paper is structured as follows: the following section is a literature review; in section 3, we introduce TOPSIS technique and present the drivers' data of dimensions of food and nutrition security; section 4 reports our results. The final section includes the conclusions.

2. Literature Review

Food and nutrition security is a multi-dimensional subject. The definition "when all people at all times have access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" given by the Food and Agricultural Organization

(FAO) in 1996 describes four core dimensions of food and nutrition security. It includes physical availability of food, economic and physical access to food, food utilization and stability of the other three dimensions. Therefore, assessments based on one dimension are not sufficient (Aubin, 2013). To assess multiple dimensions' concepts, multi-criteria tools are often used.

Multi-Criteria Decision Aid (MCDA) or Multi-Criteria Decision-Making (MCDM) approaches have received considerable attention from researchers when measuring, estimating and ranking alternatives or options across various disciplines including mathematics, behavioral decision theory, economics, and computer science, software engineering and information systems (Behzadian *et al*., 2012). Multiple criteria decision-making is a sub-discipline of operations research and management science that uses mathematical and computational planning to support the assessment of a number of decision alternatives under a number of criteria by decision-makers (Lootsma, 1999) who make the choice between alternatives (Marsh, 2016) or the final decision related to the research objectives.

Since the 1960s, many theoretical and empirical papers and books have applied multi-criteria decision-making models (Roy, 2005). Over the time, the role of multi-criteria decision-making methods in diverse application research has enhanced considerably, as new methods have developed and old methods have improved (Velasquez and Hester, 2013). A multi-criteria decision-making problem, with set alternatives, is briefly specified in a matrix format, from which decision-makers should select the best alternative related to the criteria (Jahanshahloo *et al*., 2009). The basic components of diverse multi-criteria decision-making models are the same. There is a limited or unlimited set of alternatives, at least two criteria and one decision-maker (Salvatore, 2005). With these essentials, multi-criteria decision-making supports decision-makers principally by choosing the preferred alternatives, or by identifying a set of dominated alternatives with the aim to reduce uncertainties in making decisions (Jahanshahloo *et al*., 2006).

Amongst several multi-criteria decision-making approaches developed to answer real-world decision issues, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) works adequately across diverse application areas (Bartolini and Viaggi, 2010). The application areas using TOPSIS technique are Supply Chain Management and Logistics, Engineering and Manufacturing Systems, Business and Marketing Management, Health, Safety and Environment Management, Human Resources Management, Energy Management, Chemical Engineering, Water Resources Management, Medicine, Agriculture, Education, Design, Government, and Sports (Behzadian *et al*., 2012).

As received from several studies, prevalence of food and nutrition insecurity is happening in Iran (Abolhassani *et al*., 2015; Golami and Foruzanfar, 2015; Rezazadeh *et al*., 2015; Yaghoobi *et al*., 2015; Alipour *et al*., 2016; Behzadifar *et al*., 2016). Therefore, we have attempted to quantify and evaluate the multiple impacts on all four dimensions of a food system in delivering food and nutrition security using TOPSIS as a multi-criteria technique, and consequently we may find the most vulnerable dimensions. Hence, by identifying the main weaknesses in food systems, our work may help decision-makers to implement policies that reduce food and nutrition insecurity in a country.

3. Methodology and Data

3.1. TOPSIS

Decision-making is the process of discovering the best or dominated decisions among all the possible alternatives. Conflict among criteria is the prevalent situation and thus, there may be no solution to fill all criteria at the same time yet, decision-makers have to solve a multiple-criteria decision-making problem (Jahanshahloo *et al*., 2009). Numerous techniques have been created and utilized to answer multiple-criteria decision-making problems (Hwang, 1981; Zeleny, 1982). The Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) is among them (Hwang and Yoon, 1981). Many theoretical and empirical works have used TOPSIS method. Since the year 2000, 266 scholarly papers, in 103 journals from different application areas, have used TOPSIS technique (Behzadian *et al*., 2012).

TOPSIS technique is a multiple-criteria technique designed to recognize key alternatives. The basic idea is that the selected alternative should have the closest distance from the positive ideal solution and the farthest distance from the negative ideal solution (Hwang and Yoon, 1981) in a multi-dimensional computing space (Qin *et al*., 2008). The positive ideal solution maximizes the benefit criteria (which higher values indicate a more positive) and minimizes the cost criteria (which higher values indicate a more negative), while the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. TOPSIS uses all criteria information, offers principal ranking of options, and does not require criteria to be independent (Chen and Hwang, 1992; Yoon and Hwang, 1995).

TOPSIS is one of the most applied techniques to solve real-world issues. It has various advantages like having: a) an ability to identify the best alternative quickly, b) a simple process, c) programmable and easy to use, and d) the same number of steps regardless of the number of criteria (Zaidan *et al*., 2015). Its disadvantages are that it does not consider the correlation of criteria, and it is difficult to weight the criteria (Velasquez and Hester, 2013).

Other multiple-criteria decision-making methods have confirmed the results, which are obtained through using TOPSIS technique (Velasquez and Hester, 2013). Hence, TOPSIS is appropriate for the cases with a large number of criteria and alternatives and it is especially accessible when

quantitative data are specified (Zaidan *et al*., 2015). The mathematical steps for the calculation of a multiple-criteria decision-making case through TOPSIS technique are:

Step 1: Define the problem and construct a raw decision matrix. To construct a raw decision matrix in this study, alternatives, which are defined indicators, considered as rows and criteria, which are defined years in this paper, considered as columns.

Step 2: Calculate the normalized decision matrix, which the normalized value obtains as equation one. Normalization rebases the raw indicator data to a common unit, so that it can be aggregated (Prosperi, 2014).

$$r = x_{ij} / \sqrt{\sum_{i=1}^{m} x_{ij}^2} \qquad i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, n \quad (1)$$

x shows the score of each indicator in each year and *r* is the normalized score of each indicator.

Step 3: Calculate the weighted normalized decision matrix, which the weighted normalized value obtains as equation two. The summation of weights has to be equal one (Saaty, 1977, 1994 and 2000).

$$v_{ij} = r_{ij} \times w_{ij} \quad i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, n \quad (2)$$

w is the weight related to each indicator and *v* shows the weighted normalized scores for each indicator.

Available weighting methods can combine with classical TOPSIS to improve the disadvantage related to the weights. There are three groups of methods to weight criteria: a) subjective methods, where a decision maker assigns the importance of the criteria, b) objective method, where the decision-maker is not determining the importance of the criteria, and c) weighting method that combines the two previous methods (Jahan *et al*., 2012). In subjective weighting, a Pair-Wise comparison is a popular technique, where policy makers are asked to compare the criteria importance at the same time. In objective methods, weights are found based on the data of the recognized issue. Objective methods are mainly suitable for conditions with unavailable reliable subjective weights (Leung and Cao, 2000) introduced by a decision-maker (Jahanshahloo *et al*., 2009). The entropy method gives weights objectively. This technique is very promising, simple, and convenient to determine the weights (Chen *et al*., 2015). When leaders recognized that theses subjective and objective weights are not suitable for the criteria, they combine and adjust the weights (Zadeh *et al*., 2013).

Step 4: Determine the positive and negative ideal solutions (x^+ and x^-) that indicates the best and worst indicators values. The positive ideal solution is for the indicators which a higher value indicates a more positive environment for food and nutrition security and the negative ideal solution is for the indicators which a higher value indicates a more negative environment for food and nutrition security (EIU, 2015).

Step 5: Calculate the distance from every ideal solution. We can find these distances as:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (x_{ij} - x_j^+)^2}, \quad i = 1, 2, \dots, n \quad (3)$$

$$d_i^- = \sqrt{\sum_{j=1}^{m} (x_{ij} - x_j^-)^2}, \quad i = 1, 2, \dots, n \quad (4)$$

d^+_i is the difference of each indicator with the best value (maximum value for the benefits) and d^-_i is the difference of each indicator with the worst value (maximum value for the costs).

Step 6: Calculate the complete assessment index for each alternative as:

$$C_i^* = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1, 2, \dots, n \quad (5)$$

Step 7: Arrange the order of alternatives from the best to the worst based on complete assessment index, where the best has the highest value. The complete assessment index has values between zero and one and when it is near to one, it indicates that the alternative or indicator is close to an optimal level.

Step 8: Provide the decisions by decision-makers who recognize the final decision due to the estimated results for different indicators (Marsh *et al*., 2016) by different years (Thokala, 2016). In the present study, the decision is to synthesize an index for food and nutrition security, to discover how each indicator has affected food and nutrition security, and to find how food system is vulnerable or resilient to what indicator.

The complete assessment index calculated in the step six could be a dynamic quantitative national level index for food and nutrition security. However, an index, even a carefully constructed one, is only a tool. As an overview, the index provides accessible insights through scores obtained to highlight strengths, weaknesses, and progress over the years. By reducing major food and nutrition security indicators to their core components, the index provides a useful approach to understand the risks threatening food systems in countries, and as a consequence in the delivering of food and nutrition security. The index is intended to foster discussion about the drivers of food and nutrition insecurity and to suggest areas in which policy-makers and other stakeholders should focus their efforts in order to have the greatest impact.

3.2. Data

An indicator should reflect an assumed condition or an underlying reality; hence, there is no best indicator, best measure of an indicator, or best analysis (Habicht and Pelletier, 1990). There are several sources of information from where to find and choose the indicators of food and nutrition security including: a) Food and Agriculture Organization of the United Nations (FAO), b) World Health Organization (WHO), c) World Bank, and d) Global Food Security Index (GFSI) of the Economist Intelligence Unit (EIU) .

The choice of food and nutrition security indicators (that are variables which affect food and nutrition security) require a theoretical framework, since the composite indexes,

which combine food and nutrition outcomes and drivers, make it hard to deduce policy reactions (Hanie *et al*., 2013). In this paper, we use the FAO definition of food and nutrition security in choosing indicators as suggested by Hanie *et al*. in 2013.

For the overall goal of this paper, we use food and nutrition security indicators calculated from 1992 to 2011 available at the FAO website. The list of all 36 indicators available from official statistics is presented in table 6 of Annex 2. In the analysis, we have excluded those indicators that do not have full coverage of the considered years.

Although it does not require criteria to be independent in TOPSIS application (Chen and Hwang, 1992; Yoon and Hwang, 1995), models with lower number of criteria are expected to be more sensitive to the changes in criteria weights and be capable of producing ranking (Yurdakul and Tansel IC, 2009). Different studies offer critical insights associated with the importance of choice criteria (Yurdakul and Tansel IC, 2009). Based on the theory of Miller, seven plus or minus two, represent the greatest amount of information, which an observer can provide us about an object and a complete judgment (Miller, 1965).

Therefore, based on Miller's theory and on the same conception of model indicators and by diminishing the second disadvantage of TOPSIS, i.e. not considering the correlation of criteria, we reduced the number of indicators as reported in table 1.

Among the indicators of availability dimension, we chose the adequacy of average dietary energy supply and the average value of food production, since these indicators cover the share of dietary energy supply derived from cereals, roots and tubers, the average protein supply and the average supply of protein of animal origin. In access dimension, we incorporated the rail and road density indicators due to the same reason. The indicators of prevalence of undernourishment, i.e. depth of the food deficit and prevalence of food inadequacy, are removed as they are complementary and they can be interpreted by the gross domestic product indicator. Amongst the indicators available for stability dimension, the percentage of arable land equipped for irrigation, the value of food imports over total merchandise exports and per capita food supply variability have been chosen. Value of food imports of the total merchandise trade covers cereal import dependency ratio and per capita food supply variation can indicate per capita food production variability. For the utilization dimension, we have incorporated the access to improved water and the access to improved sanitation into one indicator; and the prevalence of anemia among pregnant women and among children under five years of age as the second indicator.

Table 1 - *A selection of food and nutrition security indicators from 1992 to 2011.*

CXCKNCDKNV["	CEEGUU"
-" Cxgtci g"fkgvct{ "gpgti { "uwrr{ "cf gs vce{ "*lpf lecvqt"3+#	-" Tqcf "cpf "Tcknlff gpuk{ "*lpf lecvqt"3+#
-" Cxgtci g"xcnwg"qh"hqqf "r tqf wevkqp"*lpf lecvqt"4+#	-" I tquulf qo gunle"r tqf wev"r gt"ecr kc" *lpf lecvqt"4+#
UVCDKNV["	**WKNK{ CVIQP"**
-" Rgtegpv" qh" ctcdng" ncpf " gs vkrr gf " hqt" kttli cvkqp" *lpf lecvqt"3+#	-" Ceegukvq"lo r tqxgf "y cvgt"uqwteu"cpf " ucpkcvkqp"lncekddgu"*lpf lecvqt"3+#
-" Xcnwg" qh"hqqf "lo r qtvu"qxgt"vqcn"o gtej cpf kug"gz r qtvu' *lpf lecvqt"4+#"	-" Rtgxcngpeg"qh"cpgo lc"co qpi "r tgi pcpv" y qo gp"cpf "ej kn tgp"vpf gt"7"{ gctu"qh"ci g" *lpf lecvqt"4+#
-" Rgt"ecr kc"hqqf "uwrr{ "xctlcdkk{ "*lpf lecvqt"5+#	

Source: FAO website.

4. Results and Discussion

4.1. Results

Using TOPSIS technique, we have calculated a dynamic quantitative national level index of food and nutrition security and the index for each dimension of food and nutrition security for Iran. The raw data of food and nutrition security, of the 19 available indicators, were collected from FAO website for the period of 1992-2011 and summarized into nine indicators.

Then we normalized the data by using equation 1 and constructed weighted normalizing matrix by using equation two. We adopted the theory and suggestions of FAO experts to determine subjective weights. Based on their comments, all dimensions have the same weight. In addition, we measured the objective weights through an entropy method and combined these two subjective and objective weights to validate our results. The weights calculated through these three methods are presented in table 5 of Annex 1.

The positive and negative ideal solutions that indicate the best and the worst behavior of each indicator are presented in table 7 of Annex 3. For the benefits, the indicators which a higher value indicates a more positive environment for food and nutrition security, the maximum value is the best solution and the minimum value is considered as the worst solution. While for the costs, the indicators that a higher value indicates a more negative environment for food and nutrition security, the minimum value represents the best and the maximum value the worst solution. The distance of each alternative from positive and negative ideal solution, was determined by using equations three and four presented in table 8 of Annex 3, and they maximize the benefits and minimize the costs from each ideal solutions.

Using equation five, we assessed the overall score for each indicator during the time in order to rank and compare the indicators in delivering food and nutrition security, see table 2. We then created a national level composite index for each dimension of food and nutrition security by calculating the average of estimated overall indicators located in each dimension that reported in figure 1. In addition, we have computed an overall dynamic quantitative national level index of food and nutrition security of Iran, see table 2. All determining methods give results that are learning to the same direction for each analyzed dimension.

The results in table 2 indicate that the gap between the worst and best performers narrowed. The evaluated calculated scores for the indicators are not very far apart, 0.431 for the worst and 0.575 for the best score. The standard deviation is about 0.054 and shows that almost all indicators

have the same behavior. As mentioned before, a near to one, indicates that the option is closer to optimum level while a score close to zero, indicates the opposite, i.e. non optimum level. So higher scores of the evaluated index show a better situation for both indicators and dimensions. Between the indicators measured by the model, the average dietary energy supply adequacy is located at the bottom, as the worst performing indicator in the food system. On the other hand, per capita food supply variability is located at the top, as the best performing indicator in the food system.

Figure 1 shows that the value of the composite availability dimension index is 0.49. Regarding the indicators forming the availability dimension, average dietary energy supply adequacy had the largest decrease within the dimension with a score of 0.43, while average value of food production had the largest increase in this dimension with a score of 0.55. Therefore, according to this dimension, food and nutrition security in Iran is vulnerable in relation to average dietary energy supply adequacy and resilient in relation to average value of food production (table 2).

The composite index of access dimension is 0.47 (figure 1). Among the indicators of access dimension, the weakness in gross domestic product per capita, in purchasing power equivalent, was the main factor behind the fall in scores in the access category, with its score of 0.44. Rail and road density indicator was the main factor in improving the score of this dimension with a value of 0.50. So consequently, the access dimension of food and nutrition security in Iran is vulnerable to gross domestic product per capita, in purchasing power equivalent, as an economic access indicator and resilient to road and rail density as a physical access indicator.

The composite index of stability dimension is 0.54 as shown in figure 1. The value of food imports over total merchandise exports and the percentage of arable land equipped for irrigation with scores near to 0.52 had the worst performances, while per capita food supply variability with a score of 0.57 had the best performance in the stability dimension of Iranian food and nutrition security. Consequently, according to this, Iran is vulnerable to the value of food imports over total merchandise exports and the percentage of arable land equipped for irrigation while being resilient to per capita food supply variability.

The last composite index, utilization dimension, has a value around 0.52 as shown in figure 1. Based on table 2, access to improved water sources and sanitation facilities are the worst among utilization indicators with a value of 0.46. The best indicators in this dimension are prevalence of anemia among pregnant women and children under 5 years of age with a score of 0.57. So utilization dimension of food and nutrition security in Iran is vulnerable to access to improved water sources, sanitation facilities, and resilient to prevalence of anemia among pregnant women and children under 5 years of age.

As presented in table 2, the overall index of food and nutrition security in Iran obtained by using this technique, is 0.51. Although this value does not describe a risky situation, it, however, is not close to an optimum level as mentioned above; scores near one are close to optimum level. The score of overall evaluated index of food and nutrition security, (figure 1) shows the behavior of food system delivering the four dimensions of food and nutrition security in Iran. From figure 1, it is possible to observe that the access dimension is the main problem. Food system has not operated well in delivering access to food in Iran and especially economic access, as seen in table 2, makes Iranian food system vulnerable to access dimension in delivering food and nutrition security. After access dimension, the availability dimension is worse placed within Iranian food system. This dimension has not functioned well in delivering average dietary energy supply adequacy as reported in table 2 which it means that the food system in Iran is vulnerable also to the availability dimension in delivering food and nutrition security. Utilization and stability dimensions are placed better and indicate more resilience, but are relatively distant from desired optimum level values in their scores.

Table 3 presents the calculated results of the index, over the years, for four core dimensions of food and nutrition security in Iran. We have calculated the index for each dimension of food and nutrition security of study the period by dividing it into five-year periods in order to receive the trend of change in delivering food and nutrition security in Iran. As table 3 shows, availability and access dimensions have continuously decreased over time, as can be seen from table 4. Availability dimension has been more vulnerable during the period from 1997 to 2006 (-8.1) and more resilient during the period from 2002 to 2011 (-1.11). Access dimension has been more vulnerable between 2002 and 2011 (-9.8) and more resilient between 1997 and 2006 (-0.93). Stability dimension has improved from 1992 to 2001 with a score of +7.8 points and showed more resilience within this period. Nevertheless, after 2001, values of stability dimension have declined and this dimension has been more vulnerable between 2002 and 2011 with the score of -5.2 points. Utilization dimension on the other hand im-

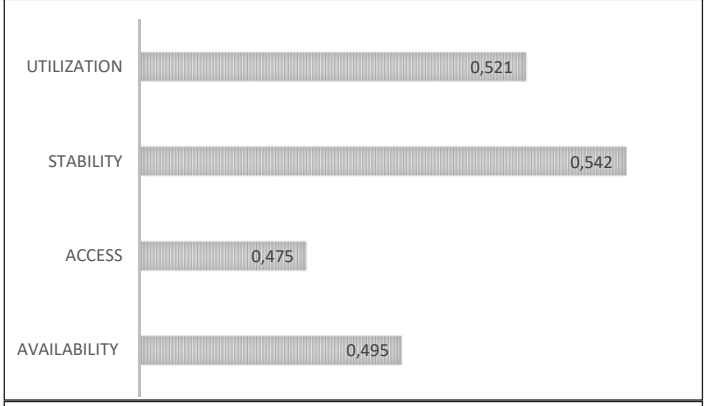
Table 2 - *Results of national level index of food and nutrition security and ranking of indicators in Iran.*

Hpf lecvqtu'	**E R'**	**T cpm'**
C xc lwc dlddv{ "	**"**	**"**
C xgtci g"f lgvct{ "gpgti { "uvr r rj "cf gs wce{ "	206539"	; "
C xgtci g"xcnvg"qh"hqqf "r tqf wcvkqp"	207; 7"	5"
C eeguu'	"	"
Tqcf "cpf "T ch"f gpuk{ "	207288"	8"
I tquu'f qo guule"r tqf vev"r gt"ecr kc"	206668"	: "
Uvcdlddv{ "	"	"
Rgtcegpv"qh"ct cdng"hcpf "gs wkr r gf "hqt "ltdli cvkqp"	207494"	6"
Xcnvg"qh"hqqf "lo r qtu'qxgt"vqvcn"o gtej cpf kug"gzr qtu'	207477"	7"
Rgt"ecr kc"hqqf "uvr r rj "xct lcdlddv{ "	2097: "	3"
Wkdk cvkqp"	"	"
C eeguu'vq"lo r tqxgf "y cgt"uqwtegu'cpf "ucpkvcvkqp"lceddlddgu'	208: : "	9"
Rtgxcngpeg"qh"cpgo lc"co qpi "r tgi pcpv"y qo gp"cpf "ej kf tgp"vpf gt "?"{ gctu'qh"ci g"	207962"	4"
Qxgt cnlpf gz."	**207348"**	"

Source: own calculations.

proved from 1997 until 2006 with a score of +16.11. However, between 2002 and 2012, this dimension decreased with the score of -5.3 points and from 1992 to 2001 utilization dimension has been more vulnerable with a score of -12.9 points.

Fig. 1. *Scores of dimensions of food and nutrition security in Iran.*



Source: own calculations.

Table 3 - *Scores of dimensions of food and nutrition security in Iran over the years.*

F lo gpukqp"""""	3; ; 4/; 8"	3; ; 9/23"	4224/28"	4229/33"
Cxclkecdkkv{"	207: 5: "	207585"	20679: "	206749"
Ceegcu'	2077: 6"	207588"	207538"	2069; 7"
Ucvcdkkv{"	206692"	206: 42"	206943"	206697"
Wkkk{cvkqp"	207327"	206665"	20737; "	206: ; ; "

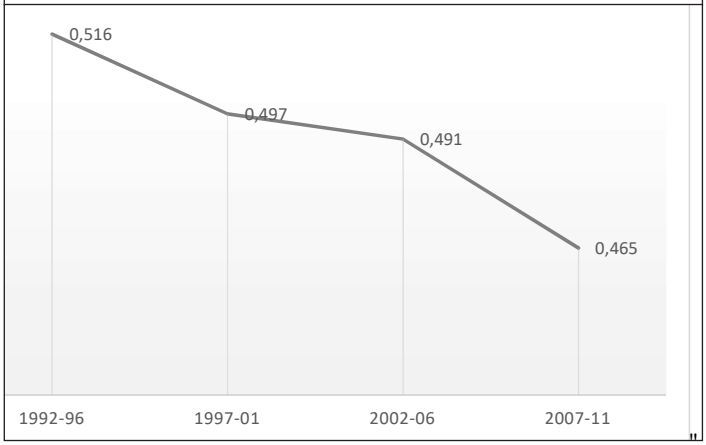
Source: own calculations.

Table 4 - *Changes of dimensions of food and nutrition security in Iran.*

F lo gpukqp""	3; ; 4/; 8"\q"3; ; 9/23"	3; ; 9/23"\q"4224/28"	4224/28"\q"4229/33"
Cxclkecdkkv{"	/: 08"	/3608"	/3083"
Ceegcu'	/50 "	/20 5"	/; 0 "
Ucvcdkkv{"	- 90 "	/4027"	/704"
Wkkk{cvkqp"	/340 "	- 38083"	/7025"

Source: own calculations.

Fig. 2. *Trend of food and nutrition security in Iran.*



From these results, we can deduce that there have not been improvements in the dimensions of food and nutrition security in the overall score of food and nutrition security index as figure 2 demonstrates. Figure 2 shows, food and nutrition security has been declining in Iran and especially within the last five years, from 2007 to 2011, the decline has sharpened.

4.2. Discussion

An individual indicator is not able to capture the complexity and multidimensionality of food and nutrition security, and measuring the complexity of food and nutrition security is part of wider debates that currently happens in the research process of the post-2015 development agenda (FAO, 2013). On the other hand, the dynamic nature of food and nutrition security is implicit (FAO, 2008). Therefore, we have applied TOPSIS technique to consider these issues as in the previous quantifications of food and nutrition security as the one EIU has not been measured.

As Economist Intelligence Unit (EIU) defines in calculating the Global Food Security Index, scores above 0.75 of any indicator indicate strengths, while scores under 0.25 indicate challenges. Using these thresholds, a food system is vulnerable when food and nutrition security performance reaches the lower bound and it is resilient when it reaches the upper limit. According to these limits, no indicator and no dimension is at challenge and nor at strength in Iran. Hence, food system in Iran is not reaching top levels in any dimension of food and nutrition security.

Food availability plays a prominent role in food and nutrition security. Two main indicators were selected in the present study: they are average dietary energy supply and average value of food production. In this dimension, the average dietary energy supply adequacy, a percentage of the average dietary energy requirement, is the indicator, which is vulnerable in Iran. As FAO defines, this indicator expresses the average supply of calories for food consumption. As we found, the food system in Iran does not supply enough calories that leads to prevalence of undernourishment.

The capability to access food reposes on two physical and economic accesses. Two indicators were chosen in this study: road and rail density as physical access and gross domestic product per capita as economic access. In Iran, the vulnerability of access dimension is related to gross domestic product per capita based on purchasing power parity. Gross domestic product per capita based on purchasing power parity is gross domestic product transformed into international dollars using purchasing power equality rates related to FAO definition. This indicator provides information on the possibility of economic access to markets. Therefore, this index shows that Iranians do not have enough economic power to receive adequate dietary energy. Low purchasing power can theoretically increase the prevalence of undernourishment, the gravity of food deficit and the prevalence of food inadequacy. Therefore, food system in Iran is not resilient in relation to economic access when delivering food and nutrition security. Not having enough

economic power to purchase safe and nutritious food has caused that the population consumes an amount of calories that is insufficient to cover their energy requirement for an active and healthy life. Hence, the prevalence of undernourishment, the food deficit and food adequacy have occurred according to the strategic analysis paper by Heslot in 2014 due to similar consequences.

Two important features of stability, namely those that relate to food supply and food price. The key indicators were selected here: percentage of arable land equipped for irrigation, value of food imports over total merchandise exports and per capita food supply variability. In the present study, the vulnerability of stability dimension is linked with the arable land equipped for irrigation and food imports that measure the dependence of agriculture of a country on irrigation. Since water stress and climatic shocks make agriculture vulnerable, the food system in Iran is vulnerable to water and climate change in delivering food and nutrition security that depends on production levels. The value of food import provides a measure of vulnerability and it captures the adequacy of foreign exchange reserves needed to pay for food imports. As the results show, food system in Iran is vulnerable to the variation in exchange rates for national food and nutrition security that depend on trade patterns.

Food utilization includes two different aspects. Anthropometric indicators affected by under nutrition that are widely available for children under five years of age and women and the second aspect is captured by a number of determinants or input indicators that reflect food quality determining how effectively available food can be utilized. Two core indicators available for the country during the period are access to improved water sources and sanitation facilities and prevalence of anemia among pregnant women and children under 5 years of age. In Iran, in utilization dimension, food system is vulnerable due to poorer access to improved water resources and sanitation facilities. FAO defines the access to an improved water source as the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to excreta disposal facilities that can effectively prevent human, animal, and insect contact with excreta. Food system in Iran has not provided enough access to neither water nor sanitation sources in delivering adequate food and nutrition security.

In relation to the results of food and nutrition security analysis over time, we have found that Iranian food system has been vulnerable in all dimensions of food and nutrition security. Based on this, vulnerability is present in all factors and that places people at risk, as food might be insecure. During the study period, among all dimensions, availability and access were more vulnerable as they continuously declined especially in supplying energy from consumed food, and in purchasing power parity in order to enable consumers to purchase a food basket that is healthy and has enough food. From the long-term perspective, stability and utilization, although they do not stand in a desired level, show more resilience compared with other dimensions of food and nutrition security in Iran. Stability dimension's resilience has nevertheless declined in relation to climate change during this period in Iran. Utilization dimension's resilience has also declined in respect to the access people have to water and sanitation resources.

Policy-makers in Iran have to invest in agricultural sector. Due to climatic and topographic conditions, soil salinity and water scarcity, agricultural production is restricted to a few crop varieties and in a restricted production area. Through improvements in irrigation systems, food system in Iran will be successful in increasing the crop's yield in a limited area and consequently improving the availability dimension of food and nutrition security. Policy-makers need also to focus on expanding genetically modified crops that could benefit the agricultural sector and improve availability dimension. Improvements in marketing systems are also needed in order to improve availability dimension through decreasing agricultural wastes that FAO evaluates of being around 30.7 percent of agricultural production in North Africa and in Central and West Asia. We found that stability dimension is vulnerable in relation to climate change, so these improvements will decline this vulnerability also. Because of dependence of international trade and not having enough soil and water to produce all required food for the population, policy-makers have to control exchange and inflation rates so as to improve available income of people by improving international decision-making. These improvements will improve the access dimension of food and nutrition security in Iran. Utilization dimension should be improved through investments in water and sanitation resources. These improvements will make the food system more resilient to the internal and external pressures and shocks. Public-private partnerships are crucial in obtaining progress in structural elements of food and nutrition security.

5. Conclusion

The dynamic quantitative national food and security index, calculated by TOPSIS technique, is constructed from nine unique indicators that measure these drivers of food and nutrition security. This index is the first to examine food and nutrition security comprehensively across the four nationally established dimensions. Moreover, the study looks beyond food and nutrition security by underlining the factors affecting vulnerability and resilience of food system and food and nutrition insecurity. This is a

new application of TOPSIS to assess food system of a country and to find the most important challenges and strengths, in delivering the most important goal, food and nutrition security. Using this quantitative method, we have found the changing trend in food and nutrition security when trying to understand if food system has improved or worsened over time. To have a policy impact, this approach aims to help decision-makers to establish the necessary structures that enable food systems to operate effectively. We found out that in Iran, none of the dimensions of food and nutrition security comes close to the desired level and that they even have worsened over time. Food system in Iran is vulnerable in providing energy sources to consume, financial resources to purchase, exchange rate to import, climate change to produce and to access sanitation resources. Therefore, policy-makers in Iran have to invest in agricultural sector by improving irrigation and marketing systems to increase productivity, produce more safe food, and decrease the agricultural wastes so that these investments will improve the availability and utilization dimensions of food and nutrition security. Moreover, they have to control inflation and exchange rates to increase purchasing power of people and to improve access and stability dimensions of food and nutrition security. Therefore, food system will be more resilient to the internal and external pressures and shocks in delivering food and nutrition security as the main goal.

For further research works, we propose that this technique should be used to compare food systems in delivering food and nutrition security in the countries across the world to find out the most and the least vulnerable food systems from the point of view of food and nutrition insecurity and consequently to understand the policies applied in the best environments. We also propose using this technique in the cities across the countries to find regions facing food and nutrition insecurity and poverty. The country or city comparison module allows a quick comparison of any two countries or cities in the model and individual indicators can be examined in detail. The index also allows both the overall and the category scores to be correlated with external factors that may influence food and nutrition security.

Annex 1 - *The calculated weights through of three methods.*

Table 5 - *The weights of indicators.*

Kpfkecvqtu"	Uvdlgevkxg"y gki j vu"	Qdlgevkxg"y gki j vu"	Eqo dkpgf "y gki j vu"
Cxckncdkrkv{ "	"	"	"
Kpfkecvqt"3"	20:472"	20:366"	20:4: 2"
Kpfkecvqt"4""	20:472"	20:356"	20:48; "
Ceeguu"	"	"	"
Kpfkecvqt"3"	20:472"	20:359"	20:494"
Kpfkecvqt"4""	20:472"	20:343"	20:476"
Wvknk{ cvkqp"	"	"	"
Kpfkecvqt"3"	202: 52"	20:35: "	202: 6: "
Kpfkecvqt"4""	202: 52"	20:242"	202983"
Kpfkecvqt"5"	202: 52"	20:247"	202986"
Uvcdkrkv{ "	"	"	"
Kpfkecvqt"3"	20:472"	20:366"	20:4: 2"
Kpfkecvqt"4""	20:472"	20:355"	20:48: "

Source: own calculations.

Annex 2 - *List of indicators of food and nutrition security in FAO website.*

Table 6 - *The indicators of food and nutrition security.*

CXCKNCDKNKV["
Cxgtci g"f kgvct{ "gpgti { "uwrrn{ "cf gswce{ "
Cxgtci g"xcnwg"qh"hqqf "rtqf wevkqp"
Uj ctg"qh"f kgvct{ "gpgti { "uwrrn{ "f gtkxgf "htqo "egtgcnu."tqqvu"cpf "vwdgtu"
Cxgtci g"rtqvgkp"uwrrn{ "
Cxgtci g"uwrrn{ "qh"rtqvgkp"qh"cpko cn"qtki kp"
CEEGUU"
Rgtegpv"qh"rcxgf "tqcf u"qxgt"vqvcn"tqcf u"
Tqcf "f gpukv{ "
Tckn"nkpg"f gpukv{ "
I tquu"f qo guvke"rtqf wev"rgt"ecrkvc"*kp"rwtej cukpi "rqy gt"gswkxcngpv+"
F qo guvke"hqqf "rtkeg"kpf gz"
Rtgxcngpeg"qh"wpf gtpqwtkuj o gpv"
Uj ctg"qh"hqqf "gzrgpf kwtg"qh"vj g"rqqt"
F grvj "qh"vj g"hqqf "f ghkekv"
Rtgxcngpeg"qh"hqqf "kpcf gswce{ "
UVCDKNKV["
Egtgcn"ko rqtv"f gr gpf gpe{ "tcvkq"
Rgtegpv"qh"ctcdng"ncpf "gs wkrrgf "hqt"kttki cvkqp"
Xcnwg"qh"hqqf "ko rqtvu"qxgt"vqvcn"o gtej cpf kug"gzrqtvu"
Rqnkvkecn"uvcdkrkv{ "cpf "cdugpeg"qh"xkqngpeg1vgttqtkuo "
F qo guvke"hqqf "rtkeg"xqncvkrkv{ "
Rgt"ecrkvc"hqqf "rtqf wevkqp"xctkcdkrkv{ "
Rgt"ecrkvc"hqqf "uwrrn{ "xctkcdkrkv{ "
WVKNK\ CVKQP"
Ceeguu"vq"ko rtqxgf "y cvgt"uqwtegu"
Ceeguu"vq"ko rtqxgf "ucpkvcvkqp"hcekrkvkgu"
Rgtegpvci g"qh"ej krf tgp"wpf gt"7"{ gctu"qh"ci g"chhgevgf "d{ "y cuvkpi "
Rgtegpvci g"qh"ej krf tgp"wpf gt"7"{ gctu"qh"ci g"y j q"ctg"uwpvgf "
Rgtegpvci g"qh"ej krf tgp"wpf gt"7"{ gctu"qh"ci g"y j q"ctg"wpf gty gki j v"
Rgtegpvci g"qh"cf wnvu"y j q"ctg"wpf gty gki j v"
Rtgxcngpeg"qh"cpgo kc"co qpi "rtgi pcpv"y qo gp"
Rtgxcngpeg"qh"cpgo kc"co qpi "ej krf tgp"wpf gt"7"{ gctu"qh"ci g"
Rtgxcngpeg"qh"xkvco kp"C"f ghkekgpe{ "kp"vj g"rqr wncvkqp"
Rtgxcngpeg"qh"kqf kpg"f ghkekgpe{ "
O czko wo "F kgvct{ "Gpgti { "Tgswktgo gpv"*O F GT+"

Source: FAO website.

Annex 3 - *Positive and negative ideals solutions and distances of alternative solutions.*

Table 7 - *Positive and negative ideal solutions.*

Kpfkecvqtu"	Wpf gt"uwdlgevkxg"y gki j vu"		Wpf gt"qdlgevkxg"y gki j vu"		Wpf gt"eqo dkpgf "y gki j vu"	
	Rqukvkxg"	P gi cvkxg"	Rqukvkxg"	P gi cvkxg"	Rqukvkxg"	P gi cvkxg"
Cxckncdkrkv{ "	"	"	"	"	"	"
Kpfkecvqt"3"	2024; 9"	202489"	202494"	202466"	202526"	202495"
Kpfkecvqt"4""	202543"	202439"	2024; 3"	2023; 9"	202548"	202443"
Ceegu"	"	"	"	"	"	"
Kpfkecvqt"3"	20254; "	202447"	2024; ; "	202427"	202557"	20244; "
Kpfkecvqt"4""	202568"	202432"	202548"	2023: : "	202587"	202433"
Wvknk{ cvkqp"	"	"	"	"	"	"
Kpfkecvqt"3"	202427"	202382"	2024: 3"	20243; "	202432"	202386"
Kpfkecvqt"4""	202297"	2024: 6"	2022; 5"	202572"	20228; "	202483"
Kpfkecvqt"5"	202298"	20253: "	2022; 5"	2025; 5"	202292"	2024; 5"
Uvcdkrkv{ "	"	"	"	"	"	"
Kpfkecvqt"3"	2024; 8"	202486"	202493"	202464"	202525"	202493"
Kpfkecvqt"4""	202454"	202567"	202432"	202535"	202457"	202572"

Source: own calculations.

Table 8 - *Measures of distance of alternative solutions.*

Kpfkecvqtu"	Wpf gt"uwdlgevkxg"y gki j vu"		Wpf gt"qdlgevkxg"y gki j vu"		Wpf gt"eqo dkpgf "y gki j vu"	
	f - "	f /"	f - "	f /"	f - "	f /"
Cxckncdkrkv{ "	"	"	"	"	"	"
Kpfkecvqt"3"	2022; 5"	202293"	2022: 7"	202287"	2022; 8"	202294"
Kpfkecvqt"4"	20245: "	202524"	202438"	202496"	202463"	202529"
Ceegu"	"	"	"	"	"	"
Kpfkecvqt"3"	202478"	202485"	202455"	202462"	202483"	20248: "
Kpfkecvqt"4"	20266: "	20257; "	202624"	202544"	202672"	202582"
Wvknk{ cvkqp"	"	"	"	"	"	"
Kpfkecvqt"3"	20233; "	202354"	202385"	2023: 4"	202343"	202357"
Kpfkecvqt"4"	20274: "	2027: 7"	20286; "	20293; "	2026: 6"	202758"
Kpfkecvqt"5"	202749"	202938"	202873"	202: : 7"	2026: 8"	202882"
Uvcdkrkv{ "	"	"	"	"	"	"
Kpfkecvqt"3"	2022; 2"	20229; "	2022: 4"	202294"	2022; 4"	2022: 3"
Kpfkecvqt"4"	202472"	202559"	202448"	202527"	202475"	202564"

Source: own calculations.

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