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Geo-localized Network Data Analysis Using VIKOR: Application of Network Health Monitoring in Turkey

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ABSTRACT

Middle-high level managers of operators of telecommunications have to follow many key parameters to increase the profitability along with strategy of company. Therefore, easily readable data are being provided to managers by experts. With large screens in rooms, these data are monitored momentarily and ensured to take necessary actions without creating customer dissatisfaction. Especially for operators, it is one of the key parameters to manage the network in a quality and healthy way without creating complaints. It is important to monitor network health with appointed criteria and methods. In this context, there have been weights of province-based network health by processing geolocation-based big data and using the VIKOR method. Thus, there will have been presented the network monitoring opportunity from instant real user information to managers. Although there is a lot of criteria and methods for network monitoring, it will have been one of the priority studies that will enable the analysis of geo location data with a MCDM method in this area.

Keywords : Geolocation, VIKOR, Telecommunication, Data analysis, Network monitoring

VIKOR Kullanarak Coğrafi Konumlama Ağ Verileri Analizi: Türkiye'de Ağ Sağlığı İzleme Uygulaması

ÖZ

Telekomünikasyon operatörlerinin orta-yüksek düzey yöneticileri, şirket stratejisiyle birlikte karlılığı artırmak için birçok önemli parametreyi takip etmek zorundadır. Bu nedenle, uzmanlar tarafından yöneticilere kolay okunabilir veriler sunulmaktadır. Bu veriler, odalardaki büyük ekranlar aracılığıyla anlık olarak izlenmekte ve müşteri memnuniyetsizliği yaratmadan gerekli önlemlerin alınmasını sağlamaktadır. Özellikle operatörler için, şikayet oluşturmadan ağını kaliteli ve sağlıklı bir şekilde yönetmek, önemli parametrelerden biridir. Ağ sağlığını belirli kriterler ve yöntemlerle izlemek önemlidir. Bu bağlamda, coğrafi konum tabanlı büyük veriyi işleyerek ve VIKOR yöntemini kullanarak il bazlı ağ sağlığı ağırlıkları oluşturulmuştur. Böylece, yöneticilere anlık gerçek kullanıcı bilgilerinden ağ izleme fırsatı sunulmuştur. Ağ izleme için birçok kriter ve yöntem bulunmasına rağmen, coğrafi konum verilerinin ÇKKV yöntemiyle analizine olanak tanıyan öncelikli çalışmalardan biri olacaktır.

Anahtar Kelimeler : Coğrafi konumlama, VIKOR, Telekomünikasyon, Veri analizi, Ağ izleme

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INTRODUCTION

The telecommunication sector is one of the sectors where competition is most intense. It is an undeniable fact that companies increase their profitability in order to keep up with the competitive environment depending on their strategies. Three main items have been proposed to increase profitability (Wei and Chiu 2002): (1) acquiring new customers, (2) selling more to existing customers, and, (3) retaining existing customers longer. When the churn rate decreases by 5%, the average profitability of the company increases by 25% to 85% (Jones and Sasser 1995). Companies must reduce customer movement from one provider to another (Adwan et al. 2014).

There are different criteria in the actions of customers, such as service quality components, network coverage and speed, billing, errors, technology (Ullah et al. 2019). With these factors, customers have the opportunity to easily compare service providers (Idris and Khan 2012). In this context, middle-top managers of telecom operators have to follow a lot of key parameters in order to increase profitability together with the company strategy. One of the most important of these factors is the monitoring of network quality. Since the quality of the network is greatly affected by environmental factors (activity, heavy rain, power cut, natural disaster, etc.), instant monitoring and taking immediate measures against possible problems will be key actions that will increase customer satisfaction. Considering the workload of middle and senior managers, creating visuals that can instantly monitor the network quality on the screens and direct the sub-managers and experts to take action will provide great convenience in terms of both company strategy and efficiency.

The study has been shaped with the focus on this convenience that will provide to the managers. Visualized, easy-to-read data is presented to managers by data experts. Managers have the opportunity to monitor this data through large screens in their rooms. However, these data contain mostly raw data or simple mathematical ratios and often limited network related information within approximate coverage areas. Receiving location information of a mobile device enables the delivery of more value-added applications (Roxin et al. 2007). As cloud platforms develop, more information from each customer that can affect the network can be stored for a longer period of time. Mobile customer experiences of customers instantly and at their location can be obtained as rawdata by using geolocation-based tools. With real-time geolocation, new services can be provided for a sustainable future by implementing an appropriate architecture with layers for infrastructure tools in the current telecommunications market battlefield (Dzemila et al. 2020). It is necessary to process geolocation data that will provide new services and make it usable in real life with a systematic methodology. In this context, the VIKOR method, one of the multi-criteria decision-making methods (MCDM), is a useful method that has been put forward in many studies. It was especially chosen for the study since the benefit-cost effect can be changed between the criteria. However, no study was found in which geolocation data were analyzed with MCDM methods.

In this context, province-based network health weights were created by processing geolocation-based big data and using the VIKOR method. Thus, managers will be provided with the opportunity to monitor the network from instant real user information. Although there are many criteria and methods for monitoring the network, it will be one of the priority studies in this field that will enable the analysis of geolocation data with a MCDM method.

The content of the paper is structured as follows: Chapter 2 describes the relevant literature while methods are introduced in Chapter 3, the methodology of the application is provided in Chapter 4 where evaluation of managerial is provided in Chapter 5. Finally, Chapter 6 presents the conclusions.

1. LITERATURE REVIEW

Studies have been carried out for many units of the telecom sector with multi-criteria decision making methods. Supplier selections; Önüt et al. (2009) developed a supplier evaluation approach based on the order performance technique of GSM companies. Billing unit improvements; Huang et al. (2012) worked on increasing the service quality of the cloud computing application in the billing system. Improvement and selection facilities in the services provided; Lin et al. (2016) identify the music service needs and intentions of customers and identify the selection criteria necessary for customers to evaluate and select digital music service platforms. Telecom tower installation; According to Avical et al. (2021), the criteria responsible for the telecom tower installation were found and the importance of each criterion was evaluated. Selection of network components; Pidchenko et al. (2023) increases the effectiveness of a multi-criteria approach to decision making in the process of selecting telecommunications network components, particularly a speech codec. In this context, different studies can be added. However, studies with MCDM methods in network quality units are rare. The reason for this is that it is difficult to access customer data and the estimation tools are developed in companies.

Geolocation-based solutions allow for improvements in customer locations. In this context, different geolocation-based studies are encountered. In the field of tourism; Ivanochko et al. (2021) checked the hypothesis whether sharing real-time locations of city visitors would be beneficial for selecting city attractions. According to Priandani et al. (2017) creates an Android-based historical tour guide application created using geolocation feature using location-based service technology. Media; Gonçalves et al. (2021) used it to provide information to local news editors to further develop their e-participation and news publishing activities. Health; Peixoto et al. (2020) aimed to assist public administrators with action plans and resource allocation while examining how mobile geolocation data could be used as a measure of population mobility during a pandemic. Telecom; Marquez-Barja et al. (2012) presents the Vertical Transition Decision Algorithm deployed in the vehicle's onboard unit, considering the realistic spanning model of different underlying networks such as geolocation, vehicle navigation, and Wi-Fi. In addition, there are studies developed to increase the reliability of geolocation data. Anisetti et al. (2012) A technique that provides geolocation and mobility estimation of mobile devices is presented by mixing the location information obtained with the GSM/3G infrastructure and the point matching results obtained by the camera integrated into the mobile devices. Bähr et al. (2022) focuses on the measurement quality of geolocation sensor data, with a strong focus on missing measurements.

It is planned to contribute to the literature as a study using geolocation data and MCDM methods for decision making to monitor mobile network quality.

2. METHODOLOGY

2.1. Geo-Location

Geolocation is the smart answer to the "where is the object" question using real-world geolocation. This technology can be used to track assets, people and even interact with mobile devices to provide more personalized experiences. If data is available, analysts can use this information to better understand what happened, where it is, and what to expect (Dzemyda et al. 2020). In the simplest form, the basis of the wireless geolocation system is shown in Figure 1 below.

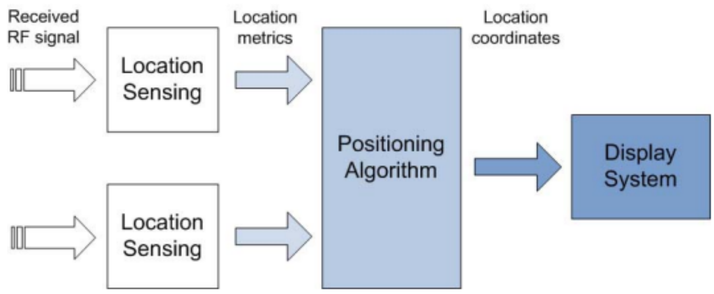

Figure 1: Wireless geolocation system (Roxin et al. 2007)

Data starts to be collected when measurement report (MR) period and GPS device are active in LTE base stations (eNODEB). A feature database is produced and engineering parameters are added. By adding the propagation model, the geolocation process is completed. The collected data can be pulled from the database.

2.2. VIKOR

VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) is a method developed for multi-criteria optimization of complex structures. In this context, it is a method that enables to determine a consensus ranking and to reach a consensus solution under the specified weights. It involves selecting the most appropriate one by determining the order of alternatives under conflicting criteria. The VIKOR method considers the multi-criteria ranking index based on closeness to the ideal solution. Consensus solution for problems with conflicting criteria helps decision makers to reach a decision. The VIKOR method was first proposed by Opricovic and Tzeng in 2004 for multi-criteria optimization of complex systems (Opricovic and Tzeng 2004).

The VIKOR method determines a consensus sorted list and compromise solution by performing a "multi-criteria ranking index" based on "closeness to the ideal". The steps of the VIKOR method can be summarized as follows:

Determined m alternatives $a_1, a_2, a_3, \ldots, a_m$, n criteria $c_1, c_2, c_3, \ldots, c_n$ and each a_j (j=1, 2, ..., m) alternative, c_i (i= 1, 2, 3, …, n) with the score corresponding to the criterion f_{ij};

Step-1: The best (f_i^*) and worst (f_i^-) values are determined for all criteria within the scope of the application. If the criterion *i* is a beneficial criterion;

$$f_i^* = max_j f_{ij} \qquad f_i^- = min_j f_{ij} \qquad i=1,2,3,\ldots,n \tag{1}$$

Step-2: S_j and R_j values are calculated for j= 1,2, ..., J. The calculation is made according to the following formulas. In formulas; S_j: j. mean group score for alternative, R_j: j. expressed as the worst group score for the alternative.

$$s_j = \sum_{i=1}^{n} w_i(f_i^* - f_{ij}) / (f_i^* - f_i^-) \qquad R_j = max_j[w_i(f_i^* - f_{ij})/(f_i^* - f_i^-)] \tag{2}$$

Step-3: Q_j values are determined for all j= 1,2, ..., J.

$$Q_j = v(S_j - S^*) / (S^- - S^*) + (1 - v)(R_j - R^*) / (R^- - R^*) \tag{3}$$

Here; $S^*=min_jS_j$ $\quad S^-=max_jS_j$ $\quad R^*=min_jR_j$ $\quad R^-=max_jR_j$

The “v” value in the formula expresses the weight for the strategy that provides the maximum group benefit, while the “1-v” expresses the weight of the minimum regret of the opponents (Opricovic and Tzeng 2007).

Step-4: S_j, R_j and Q_j values are ordered from the smallest to the largest and the order between the alternatives is determined. The smallest *j* value in the rank indicates the best option among the alternatives.

Step-5: If the following two conditions are met, the result is considered valid. However, in this case, the alternative with the minimum value can be evaluated as the most suitable.

Condition-1 (Acceptable advantage):

Q(a'')-Q(a')>=DQ

a': first-order alternative by value, a'': second-ranked alternative by value

DQ=1/(J-1); J indicates the number of alternatives.

Condition-2 (Acceptable stability):

The best value alternative a' must achieve the best score in at least one of the S and R values. If either Condition-1 or Condition-2 is not met, the compromise solution set is as follows: If Condition-2 is not met, both alternatives a' in the first order and a'' in the second order are determined as the best compromised joint solution. If Condition-1 is not met, a', a'',..., $a^{(M)}$ alternatives and value determined by $(a^{(M)})$ - Q(a') < DQ for maximum M. The best alternative ranked according to their Q values is one of the alternatives with the minimum value (Opricovic and Tzeng 2004).

3. THE METODOLOGY OF APPLICATION

The study is built on three basic stages as shown in Figure 2. The first stage consists of data collection and preparation of big data. In the second stage, the Vikor method is applied. In the third stage, the province-based final scores to be used for visualization were calculated and the study was concluded.

Since the real Long Term Evolution (LTE) mobile data of the customers in these areas is used by dividing the area of Turkey in 50x50 meter grids in the study, the collected data is too large to be processed with Office tools. Therefore, Python, the popular software tool of recent times, has been used for data preparation. For this, Python 3.11 and Jupyter (IDE) interface are used.

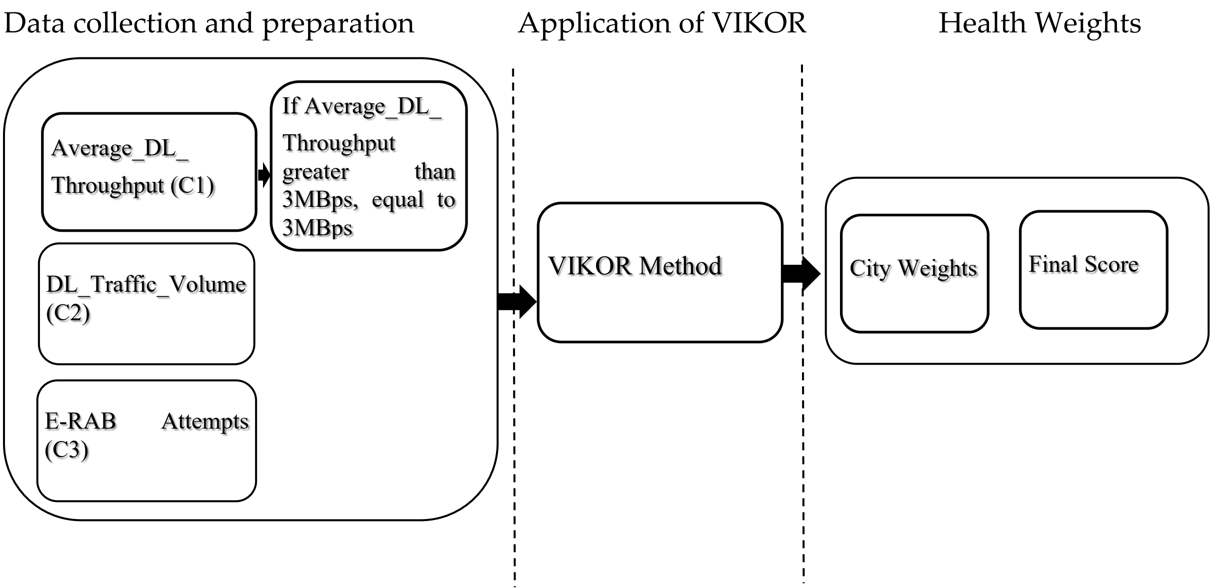

Figure 2: Steps of Application

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3.1. Data Collection and Preparation

At this stage, it is aimed to obtain data from the point where customers use mobile data in real time and transform it into usable ready data. In this context, the operator geo location tool was used to obtain data. For the date of April 10, 2023, one diary, two different files were taken.

A total of 192.422.127 lines of data were obtained, 102.102.903 lines in the first file and 90.319.224 lines in the second file.

The data obtained are Average DL Throughput (Average user mobile data rate), DL Traffic Volume (User generated traffic volume) and E-RAB Attempts (E-UTRAN Radio access bearer) key performance indicator (KPI) data for LTE technology. According to 4 experts working at the operator and asked questions, these three data are sufficient for calculating the health index for LTE mobile data speed.

These data were read with the Python program and raw data was created by adding all the data and the .csv file containing the provinces of Turkey.

In order to make the data usable after the data collection phase, data other than the 3 basic KPIs were discarded during the preparation phase. Duplicated, blank, N/A incoming rows or cells have been cleared. Finally, the values above 3 MBps are limited to 3 MBps so that very large values of the Average DL Throughput value do not disturb the normal distribution when other KPIs are added. This limit value has been determined by taking the opinions of operator experts. They have evaluated that customers will not have any customer complaints at values above 3 MBps. As a result of this step, the first 10 rows of the data were transformed as shown in Table 1 as an example.

3.2. Application of VIKOR

Especially in the study, VIKOR was determined as a suitable method because it had to be applied twice for values greater and less than 3MBps of the throughput value, and the criteria could be changed as beneficial and non-beneficial during this application. Criteria for the VIKOR method; C1: Average_DL_Throughput, C2: DL_Traffic_Volume, C3: ERAB_Setup_Attempts; alternatives were determined as 81 provinces. Q and 1-Q values were obtained by applying the 1st, 2nd and 3rd equations to the data with the Data Jupyter Notebook interface. During the application, VIKOR was applied separately for.

Table 1: Example of Shaped Data

RegionName	longitude	latitude	Average_DL_Throughput	DL_Traffic_Volume	ERAB_Setup_Attempts_Data	City
INEGOL	29,44999	40,13085	1551,221	14,311	216	BURSA
INEGOL	29,528646	40,140293	2023,6	27,626	20	BURSA
INEGOL	29,478165	40,071495	1715,362	6,327	8	BURSA
INEGOL	29,633718	40,0661	419,353	0,621	4	BURSA
INEGOL	29,502232	40,04946	2897,535	20,16	24	BURSA
INEGOL	29,51221	40,01079	487,185	0,007	8	BURSA
INEGOL	29,589106	40,01259	2399,086	0,049	8	BURSA
INEGOL	29,654263	40,059357	2979,598	0,491	4	BURSA
INEGOL	29,55917	40,066998	1974,607	10,926	24	BURSA

Average_DL_Throuhput data above and below 3 Mbit. For data above 3 MBps, beneficial for all criteria was taken, while for values below C2 and C3 beneficial, C1 was taken as non-beneficial. Because low throughput was wanted to be penalized more. However, the selected weights are taken as 0,5 for each criterion for those above 3MBps, 0,25 for C1 and C3 and 0,5 for C2 for data below. Here, too, if the throughput is low in high-traffic areas, the weight of the traffic has been increased since it is necessary to concentrate primarily on these areas. Sample Jupyter Notebook output is shown in Figure3.

3.3. Health Weights

At this stage, province weights were calculated for data above and below 3MBps by adding province information to the values calculated on 50x50 grids, and taking the arithmetic average of the grids. Finally, the total health weights of the provinces were obtained by collecting these two data (Table 2).

In line with the purpose of the study, the visualization of the Turkey map, which Telecom managers can easily see when they watch in their rooms, is presented in Figure 4.

Since there is no data from the provinces of Artvin, Kars, Ardahan and Rize, they appear as colorless in the visualization.

Table 2: Health Weights

City	Health Weights	City	Health Weights	City	Health Weights	City	Health Weights	City	Health Weights
ADANA	1,109	BOLU	1,125	GUMUSHANE	1,135	KOCAELI	1,11	SIIRT	1,115
ADIYAMAN	1,125	BURDUR	1,135	HAKKARI	1,11	KONYA	1,123	SINOP	1,143
AFYONKARAHISAR	1,125	BURSA	1,112	HATAY	1,117	KUTAHYA	1,124	SIRNAK	1,099
AGRI	1,105	CANAKKALE	1,126	IGDIR	1,131	MALATYA	1,118	SIVAS	1,131
AKSARAY	1,113	CANKIRI	1,142	ISPARTA	1,144	MANISA	1,12	TEKIRDAG	1,111
AMASYA	1,126	CORUM	1,135	ISTANBUL	1,111	MARDIN	1,098	TOKAT	1,119
ANKARA	1,121	DENIZLI	1,118	IZMIR	1,112	MERSIN	1,101	TRABZON	1,131
ANTALYA	1,116	DIYARBAKIR	1,118	KAHRAMANMARAS	1,126	MUGLA	1,115	TUNCELI	1,158
AYDIN	1,114	DUZCE	1,114	KARABUK	1,123	MUS	1,101	USAK	1,131
BALIKESIR	1,114	EDIRNE	1,117	KARAMAN	1,13	NEVSEHIR	1,131	VAN	1,109
BARTIN	1,134	ELAZIG	1,113	KASTAMONU	1,133	NIGDE	1,135	YALOVA	1,109
BATMAN	1,107	ERZINCAN	1,142	KAYSERI	1,125	ORDU	1,138	YOZGAT	1,136
BAYBURT	1,135	ERZURUM	1,136	KILIS	1,114	OSMANIYE	1,108	ZONGULDAK	1,157
BILECIK	1,132	ESKISEHIR	1,128	KIRIKKALE	1,134	SAKARYA	1,118		
BINGOL	1,123	GAZIANTEP	1,102	KIRKLARELI	1,123	SAMSUN	1,116		
BITLIS	1,117	GIRESUN	1,144	KIRSEHIR	1,135	SANLIURFA	1,095		

4. EVOLUATION OF MANAGERIAL

The findings obtained as a result of the study were evaluated in front of a monitor with 1 middle-high level manager and 2 experts working in the telecom sector. The accuracy and applicability of the results of the study together with the network experiences of the employees were discussed.

Figure 4: Weight of the provinces

First of all, managers and experts were informed about the stages of the study, how the data was collected, how it was done and the VIKOR method. Then, the employees were asked to compare the results according to their network experiences. Finally, if any, they were asked to present their suggestions.

In this context, when the results obtained are compared with the results obtained by the experts with different tools and different methods, it has been seen that they are quite consistent values. (i) It has been stated that the low network health value of the provinces in the Southeastern Anatolia region (Gaziantep, Şanlıurfa, Mardin) is a known situation and it is caused by the refugee camps and the recent Kahramanmaraş earthquake and it is necessary to invest in these areas. (ii) However, it has been evaluated that the province of Mersin received a lot of immigration after the earthquake and it may be due to the increase in population. (iii) The provinces of the Black Sea region (Ordu, Giresun, Trabzon) are said to be the provinces where the operator is strong and it is consistent. (iv) Coastal Aegean and Mediterranean provinces (İzmir, Aydın, Muğla, Antalya) were evaluated as normal with their average population/investment as of April. (v) It was conveyed that an instant assessment should be made for Sivas and that there could be a problem for different reasons at that time. One of the positive aspects of the study is that it can reflect situations where there may be an instant, unknown effect and the network may be affected.

After evaluating the results, the suggestions given are listed as follows; (i) It was said that it would be good to make an analysis and evaluate it with summer data. (ii) It was stated that the study is consistent on a provincial basis, therefore it can be applied on a district and smaller cluster basis, and it can benefit not only the management but also the experts. (iii) It may be possible to achieve different results for the network by multiplying KPIs. (iv) It can be used for additional investments for bad regions.

CONCLUSIONS

Telecom companies need to retain customers in order to increase profitability in line with their strategies. One of the important options in preventing customers from switching to different operators is the quality of the network and its sustainability. Customer satisfaction can be increased by instantaneously monitoring the network and taking precautions against potential problems. In this context, in this study, network health indexes were obtained by analyzing a method that administrators can monitor the network with geolocation data and VIKOR, which is the MCDM method. Thus, a visual was created for the administrators by painting the provinces at a certain rate.

Within the scope of the study, the data obtained from the geolocation tool was used and even the daily data consists of millions of rows. Since it is not possible to analyze this data with existing office tools, the software used for data processing has a flexible structure for data simplification and visualization and mathematical operations.

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The VIKOR method has been particularly useful in obtaining consistent results since different benefits can be selected for values above and below the 3Mps throuhput values.

It is seen that the provinces with the lowest network health index are generally concentrated in the southeastern provinces of Turkey. Here, too, it can be said that there are refugee camps, military activity and earthquake effects. However, customer satisfaction can be improved by focusing more on places where the index is low.

In future studies, by increasing the number of data days and updating the map with a dynamic structure, instant problems can be identified and measures can be taken before customer complaints occur.

The results of the study have proven to be very useful when considered in managerial evaluations and can give ideas to managers. The method will support the decisions of the managers in both instant evaluations and strategic investment decisions.

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