The Decision Model for the Internet Services in the Context of Development

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Abstract

The Internet Services in the Context of Development (ISCD) model is structured in four levels of hierarchy based on the Analytical Hierarchy Processes (AHP) theory. The model provides a formal approach of establishing the relative importance of Internet services in the context of fostering national development. This paper presents the fundamental concepts of the model. Pairwise Comparisons (PCs) technique the cornerstone of the AHP theory is used as the baseline technique for measuring the intensity of preference between the Internet traffic classes (therein their respective services they deliver to end users) in the process of formulating the judgment matrix. The ISCD model is modelled to process data obtained from a group of individual decision makers that are independent from each other. Hence decision makers are weighted in the process of aggregating their priority vectors and the normalized weighted geometric mean method (NWGMM) is used to compute the group’s priority vector, which is the final output of the model.

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1. Introduction

The development of the ISCD model is motivated by the lack of a systematic approach to address the existing hidden misalignments among the Internet stakeholders’ objectives in the present Internet architectural model [1]. Such misalignments are a part of the hindrances for the full exploitation of the Internet potentials among communities with low incomes and limited Internet Protocol (IP) based infrastructures. Evidently this is a situation especially among the Internet stakeholders in Least Developed Countries (LDCs), where the Internet is even viewed as a catalyst for enabling development [2-4]. As an intervention to address the misalignments among the Internet stakeholders’ objectives, the ISCD model introduces approaches based on a formal and

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prescriptive method for decision makers to enable them to set up policies that give high priority to accessing the Internet based/delivered services in-line of fostering development.

In some cases, setting such policies to achieve such priority levels of network performance lead to unfair and conflicting situations. As a result prioritization approaches that are at the centre of conflict management and fair grounds setting come in play as a means of negotiating a common position into some kind of decision outcome to achieve the most desired objectives with no or least expected penalties.

The concern in this study is on the perspectives of the Internet services relevance/importance to individual/homestead/national development, i.e. how the benefits accrued from their respective services meet the stakeholders’ objectives. To establish the relative importance among various Internet services is approached from the point of Internet traffic characteristics that deliver such services. On the basis that each service delivered over the Internet has corresponding applications that a stakeholder (end user) uses to achieve one’s objective. In turn, each application generates a kind of traffic over the Internet in order to deliver the required service. The number of applications (consequently the services) continues to grow daily, making it complex to make an objective comparison among ever changing numbers in the effort to establish their relative importance in the context of enabling development. Given that the present Internet traffic can be classified in a few classes regardless of the numerous applications and their respective services, therefore the various traffic classes are used for the comparison. Traffic generated by an application falls into one of the traffic classes making it easier to characterise the delivered services by their traffic class characteristics. In addition, the value/utility a stakeholder derives from the service is always matched to the cost paid to access the Internet, which is based on the rate of Internet traffic (bandwidth) required to deliver the service. So it is prudent that the relative importance of ISCD is done against the traffic classes as opposed to services. Hence the prioritization method in use focuses on achieving a priority vector of Internet traffic classes but with a view of differentiating among their external consequences (i.e. the Internet services) to stakeholders in the context of development and set grounds of aligning their misaligned objectives.

Thus this paper presents an approach for evaluating the relative importance of Internet traffic classes. On a normalized scale, the priority value of a traffic class is a true reflection of the importance/utility of that class’s delivered services to stakeholders in enabling development. Conclusively the priority vector leads the decision maker to scientific conclusion of pointing-out which Internet services are of high impact in fostering development for end users of low incomes. Consequently the priority vector can be used as a basis for setting up strategies of aligning the stakeholders’ objectives.

The rest of the paper is organized as follows; section two presents the algorithm and the blocks of the model. The algorithm gives the sequential procedure used in the process of structuring the problem. All together the blocks of the model form a frame of reference that provides the bounds for the application of the AHP theory in structuring the problem of prioritizing the Internet traffic in the context of development. These blocks (frame of reference) purposefully are geared to the role of Internet services in the context of fostering development in LDCs. Section three presents the analytical model through which a priority vector for the Internet traffic classes is derived. The mathematical procedures and aggregation methods used in the study are present here. Section four presents the conclusion of the paper and future directions to further the problem in study.

2. The ISCD model blocks

The ISCD model is constructed based on the knowledge of Internet traffic classification [1, 5, 6] in association with the services that such a traffic class delivers to end users in an environment depicting the state of infrastructure commonly found in LDCs. The detailed description of ISCD model can be found in [1] Gamukama, et al. 2014. Figure 1 is the diagrammatic representation of how knowledge is captured and formulated into the AHP based principles that can lead to the computation of the Internet traffic priority vector. At each hierarchy crucial issues in respect of (a) Internet services relevance to development, (b) affordability of such services by communities with low incomes, and (c) availability of IP based infrastructure in LDCs are considered as major parameters in the process of modelling the problem.
The top of the hierarchy defines the ultimate goal which is the prioritization of alternative elements – in this respect are the Internet traffic classes (therein respective delivered services to end users). The alternatives elements are classified as $T_1 =$ Hard real-time traffic class, $T_2 =$ Real-time non-interactive traffic class, $T_3 =$ Real-time interactive traffic class, $T_4 =$ elastic interactive traffic class and $T_5 =$ Elastic non-interactive (commonly called Best Effort) traffic class. Below the goal are the aspects/clusters. There are three aspects/clusters developed, namely (a) Services relevance in context of development, (b) Services Delivery Mechanism Convergence to IP Infrastructure and (c) Services Commensurability to Traffic Classes’ Requirements. Though generic, their development is based on well-established core factors in the scholarly
literature and ICT4D practitioners’ experiences. For computational purposes, these aspects are numbered as AS1 through AS3 respectively. Below each aspect are corresponding criteria used to evaluate it. In reference to the basic parameters for modeling the problem stated above, aspect (AS1) that focuses on establishing the weights of traffic classes’ importance based on the relevance of services it delivers to end users (communities) in LDCs has four evaluation criteria. Aspect (AS2) weighs the technological trends of convergence to all-IP in delivering services (or similar to the ones) of the traffic class in context of development. The acceptance by services providers or/and end users in LDCs to migrate to all-IP platforms to deliver/receive such services has a bearing in demonstrating the importance of such traffic class services in context of development. Three evaluation criteria identified. In consideration of the state of infrastructure in LDCs this aspect (AS3) evaluates the traffic class importance in view of its network centric and end user centric requirements. In this study network centric refers to attributes thought to be determinate in the delivery of services over IP infrastructure. The user centric focuses only the affordability of possessing a terminal equipment and continuous subscription for the Internet connectivity. Consequently three evaluation criteria are defined.

3. Foundations of preference elicitation of the model

3.1. Measuring the intensity of preference

In this model the intensity of preference between two elements is measured by use of the PCs technique. The PCs technique is based on the axiom of binary relation [7, 8]. The cardinal intensity of preference between two elements can be expressed using a ratio scale [8]. Hence is the basis of using the fundamental scale of absolute numbers [9].

3.1.1. The formal treatment of the PCs technique

With the PCs technique, only two elements at a given level of the hierarchy are compared at a time. That is, the sole purpose of the PCs technique is to enable the DM to set preferences among the elements in consideration. In the model, we let \( T = \{ T_1, T_2, T_3, \ldots T_n \} \) be a set of all possible alternatives of Internet traffic classes. Hence the requirement is to set the relative importance among traffic classes in the context of national development. Then the DM assesses the relative importance of any two elements \( T_i, T_j \in T \) by providing a ratio judgment \( J = t_{ij} \) specifying by how much \( T_i \) is preferred to \( T_j \). If the element \( T_i \) is preferred to \( T_j \) then \( t_{ij} > 1 \), if they are equally preferred then \( t_{ij} = 1 \), else \( T_j \) is preferred to \( T_i \) and \( t_{ij} < 1 \). For \( n \geq 2 \) elements compared, then a set \( T = \{ t_{ij} \} \) of all such judgments that result from making pairwise comparisons with respect to a single property or a goal is formed. The upper bound of judgments is \( n^2 \), however \( n(n-1) \) judgments are sufficient when self-comparison is not considered. The number of judgments can further be reduced to \( n(n-1)/2 \) when the reciprocal property is strictly applicable (i.e. \( t_{ij} = 1/t_{ji} \)). It also increases significantly as \( n \) increase, and becomes very large for \( n > 9 \).

The set \( T \) is represented as a square matrix and is called the PC matrix (PCM). The AHP theory proposes this technique [9] as a way of establishing and organizing all the judgments with respect to some property to be processed and synthesized along with other matrices of comparisons involved in the decision. The relationship between the elements of PCM can be depicted by means of a directional graph \( G = ( T, J ) \), where the \( n \) elements of \( T \) represents the graph nodes and \( J \) represents the set of all ratio judgments \( \{ t_{ij} \} \) as weighted edges. When a complete set of judgments \( t_{ij} \) is provided, the directional graph \( G \) becomes fully connected [8]. The DM may be an individual expert or a group of professional experts in the study subject or an agent in domain of multi-agent AI system. When the DM is presented with a set of alternatives \( T = \{ T_1, T_2, T_3, \ldots T_n \} \) to be ranked, then it is assumed that each pair of alternatives is to be compared and provide an ordinal preference judgment whether an alternative is preferred to another one \( (T_1 > T_2) \), or both are equally preferred \( (T_1 \sim T_2) \). Then for ordinal preference the property of transitivity is expected to hold \( \forall T_i, T_j \in T \). That is if
In addition it is also assumed that the DM is able to express the strength of his/her preferences by providing additional cardinal information. Basically the cardinal preference is where the magnitude of the values matter. That is if \( T_1 \) is preferred to \( T_2 \) three times and \( T_2 \) to \( T_3 \) two times then \( T_1 \) must be preferred to \( T_3 \) six times. This implies that the cardinal preference gives a much stronger requirement of consistency. Consequently the PCM is assumed to be a consistent matrix fulfilling both the cardinal and ordinal requirement properties. However because of humanistic errors there might be some level of inconsistency in the preference judgment matrix (PCM), hence rendering it neither to fulfill the ordinal nor the cardinal preference requirement. A remedy to the humanistic error is to perform a consistency test on the PCM. To reach a conclusive point of achieving the unknown preference vector, a consistency test on the PCM has to be measured to ascertain the inconsistency level in the judgments made by the DM. In this work we adopt the AHP methods in [10] for computing the consistency of a PCM. In the event that the PCM is inconsistent, detailed mathematical techniques to use are given in [9] section 5.

There are a few approaches commonly used for computing the priority vector of elements/alternatives from the judgment matrix formed during decision making process with the AHP method. In [11] the eigenvector (EV) and additive normalization (AN) methods are proposed. While the logarithmic least square (LLS) method [12] is also used. Srdjevic in [14, 15] showed that combining the different prioritization methods in AHP synthesis, based on their consistency performance at the local nodes of a hierarchy, can produce a better final result than if only one prioritization method is used in AHP. Further argues that none of the prioritization method has a priority advantage in relation to other methods if global criteria are used to compare methods of consistency. Consequently in this work we adopt the eigenvector approach in the process of computing the relative priority vector for each criterion at the respective hierarchy and then finally the global preference vector.

### 3.1.2. Computing the maximum eigenvalue of the PCM

Saaty in [11] proved the principal eigenvector of a given PCM to be used as the priority vector \( w \). The model adopts the eigenvector methodological approach. For every criterion indicated in figure 2, a PCM is formed and consequently its principal eigenvector is computed which ultimately becomes its priority vector.

The theoretical background in use for deriving the eigenvector/priority vector from a PCM is as follows; let \( w = [w_1, \ldots, w_n] \) be the unknown priority vector we wish to establish through computing the principal eigenvector of a PCM. Consider a given criterion e.g. AS1C1-User Empowerment in figure 2. Then performing all the pairwise comparisons \( P_e(T_i, T_j) ; \forall T_i, T_j \in T \), form a judgment matrix PCM "\( \mathbf{T} \)" denoted as:

\[
\mathbf{T} = \begin{bmatrix}
T_1 & T_2 & \cdots & T_n \\
T_1 & t_{11} & \cdots & t_{1n} \\
T_2 & t_{21} & \cdots & t_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
T_n & t_{n1} & \cdots & t_{nn}
\end{bmatrix}
\]

where \( t_{ij} \equiv P_e(T_i, T_j) \); \( t_{ij} = \frac{1}{t_{ji}} \) for \( i \neq j \) and \( t_{ii} = 1 \); \( \forall i = j \) & \( i, j = 1, 2, \ldots, n \); \( n \) is the number of elements in comparison; \( x, y, = 1, 2, \ldots, m \); \( m \) is the number of criteria in an aspect.

Doing a post multiplication of matrix \( \mathbf{T} \) by a vector of weights \( w \) results in \( \mathbf{T}w = nw \), which is a linear homogeneous system of equations for the unknown \( w \) and \( n \) is the dimension of matrix \( \mathbf{T} \).

\[
\begin{bmatrix}
t_{11} & t_{12} & \cdots & t_{1n} \\
t_{21} & t_{22} & \cdots & t_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
t_{n1} & t_{n2} & \cdots & t_{nn}
\end{bmatrix} \begin{bmatrix}
w_1 \\
w_2 \\
\vdots \\
w_n
\end{bmatrix} = \begin{bmatrix}
w_1 \\
w_2 \\
\vdots \\
w_n
\end{bmatrix} = nw
\]

Equivalently (2) can be presented as:

\[
(\mathbf{T} - nI)w = 0
\]
Since the matrix $\mathbf{T}$ is known then $(\mathbf{T} - nl)\mathbf{w} = 0$ can be solved to establish the unknown vector $\mathbf{w}$. From the theory of eigenvectors $\mathbf{w} \neq 0$ thus $\mathbf{w}$ is an eigenvector of $\mathbf{T}$ iff;

$$\det(\mathbf{T} - nl) = 0$$

(4)

The equation (14) is the characteristic equation of $\mathbf{T}$ and the roots of the characteristic equation are eigenvalues of $\mathbf{T}$. Since $\mathbf{T}$ has unit rank all the eigenvalues $\lambda_i, i = 1, 2, \ldots, n$ of $\mathbf{T}$ are zero except one. Furthermore, the sum of diagonal elements (trace of $\mathbf{T}$);

i.e. 

$$\sum \lambda_i = \text{tr}(\mathbf{T}) = n$$

(5)

Thus the only one $\lambda_i = n$ of $\mathbf{T}$ is called the principle eigenvalue and is denoted as $\lambda_{\text{max}}$. Equivalently (5) can be presented as;

$$\mathbf{T}\mathbf{w} = n\mathbf{w} = \lambda_{\text{max}}\mathbf{w}$$

(6)

The solution $\mathbf{w}$ of this problem is any column of $\mathbf{T}$, because all of them differ by a multiplicative constant. If this solution is normalized, the result is a unique solution no matter which column is used. Thus a ration scale [0-1] is derived which gives the relative importance of the elements under comparison.

However, the AHP approach acknowledges that the transitivity property among the entries of the judgment matrix $\mathbf{T}$ (i.e. $t_{ik} = t_{ij}t_{jk}$) does not hold as assumed in the above derivation of $\lambda_{\text{max}} = n$, because the formation of $\mathbf{T}$ involves human judgements. Hence there must be errors in $\mathbf{T}$ commonly referred to as inconsistencies. In such case the eigenvector $\mathbf{w}$ satisfies the equation $\mathbf{T}\mathbf{w} = \lambda_{\text{max}}\mathbf{w}$ and $\lambda_{\text{max}} \geq n$. The difference, if any, between $\lambda_{\text{max}}$ and $n$ is the indication of the inconsistency of the judgements. If $\lambda_{\text{max}} \approx n$ then the judgements are consistent and solves the equation (6).

### 3.1.3. Consistency test

The consistency test is designed to counter check the consistency of judgments made by the DM in the process of forming the PCM. If inconsistencies exist, then (8) is used to compute the consistency index (CI).

$$CI = (\lambda_{\text{max}} - n)/(n - 1)$$

(7)

To gain trust in the judgment process, the CI has to be assessed against judgments supported by the theory by computing the consistency ration (CR) as shown in (8). The RI of a random matrix of order $n$ is obtained from large samples of random matrices given by the theory of AHP as indicated in the table 1.

$$CR = CI/RI$$

(8)

If $CR > 0.1$ indicates that the ratio-estimates/ judgments $\{t_{ij}\}$ in the PCM tends to randomness - hence untrustworthy, consequently re-run the exercise or apply the mathematical techniques for handling inconsistent matrix [9]. Else judgments $\{t_{ij}\}$ are closer to being logically consistent, hence accepted.

<table>
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### 4. Aggregation Method

We discuss and present the aggregation method used in this study. In the real world, the AHP is often used in group settings to deliberate on the alternatives preferences/priorities of stakeholders. The group members either engage in discussion to achieve a consensus or members individually submit one’s preference which thereafter are aggregated. In this research we adopted the individual submission of one’s preference. The methods under discussion which we used are based on the later approach of aggregating individual preferences.
From a large body of literature [16-22] and references therein, the two common used methods of aggregating individual preferences are the aggregation of individual judgments (AIJ) and the aggregation of individual priorities (AIP). AIJ consists of aggregation of the individual Judgment matrices (PMCs) into one judgment PCM matrix valid for the group as a whole. Then a group preference/priority vector is computed from such matrix. While the AIP consists of aggregating the preference/priority vector from each individual participant and then compute the preference vector that represents the whole group of individual participants.

The process of deciding on which aggregation method to use involves three fundamental questions which the investigator has to address interdependently [20]. These are:
1) Is the group of the individual participants assumed to be a synergistic unit or a collection of individuals?
2) What mathematical procedures that should be used to aggregate individual judgments?
3) For not equally weighted individuals, how does the investigator obtain their weights and how such weights are incorporated in the aggregation process?

Below we present how each question was addressed to arrive at the method of aggregation used in the model.

4.1. Assumed status of the group of individual participants

The assumption of the status of the group of participants – either as a synergistic unit or a collection of individuals directs the entire process of the judgments analysis. According to theory [20], the AIJ is selected when the group of the individual participants is considered to act as a synergistic unit. In the real-world practice, this method is applicable to scenarios where individual participants are willing to or must relinquish their own preferences (values, objectives) for the good of the organization. They (all individual participants) act in concert and pool their judgments in such a way that the group becomes a new individual and behaves like one. Example of such a case is like the heads of departments making judgments to set an organization policy.

The AIP is selected when the individual in the group of participants act as separate individuals. An individual holds one’s values and objectives to judge on an issue based on his/her experience, expertise, knowledge, etc. In the real-world practice, this method is applicable to scenarios like when representatives of constituencies who have stakes in the welfare reform are set to make a new welfare reform agenda.

The ISCD is modeled to purposefully solicit for views from individual experts globally based on one’s knowledge in respect of her/his formal education in the field of applied science or development studies, experience and expertise in ICT application to solve real-world problems in developing countries. Therefore the judgments obtained from respondents are based on individual’s discrete views but all in good faith for the usage of the ICT/Internet as a tool in uplifting the standards of living for the people in least developing countries. From the theoretical and empirical findings in the previous studies above referenced, the solution to this first question automatically led us on selecting the AIP method of aggregation as to be used in this model.

4.2. Mathematical procedures for the aggregation process

The selection of AIP method automatically leads to a solution of the second question of the mathematical procedures to be used in the aggregation process. In literature [20] either the arithmetic mean method (AMM) or geometric mean method (GMM) can be used to aggregate the individual’s priorities because both fulfill the basic social choice axioms [7, 23] that are commonly applicable in AHP.

Even though either of the aggregation method “AMM” or “GMM” can be used for aggregating individual priorities, the geometric mean (GM) is more consistent in view of the meaning of priorities in AHP [20]. Preferences in AHP represent ratios of how many times more important (preferable) one factor is than another. Synthesized alternative priorities in AHP are ratio scale measures and have meaning such that the ratio of two alternatives priorities represents how many times more preferable one alternative is than the other. Consequently the model engine uses the GMM in aggregating the individual priorities (AIP). Hence, the solutions for the first two fundamental questions above are AIP and GMM respectively.
4.3. The implementation of GMM in this study

As given in (6), let \( T_1, T_2, \ldots, T_m \) be the pairwise matrices (PCMs) given by \( m \) individual participants (here-forth called decision makers); i.e. \( T_k = (t_{ij}^k)_{n \times n} \), for \( k = 1,2,\ldots,m \). Utilizing the eigenvector method in (16) the priority vector for each decision maker as shown in (21) is first computed.

\[
\mathbf{w}_k^T = [w_{1,k}, \ldots, w_{n,k}]^T \quad \text{for} \quad k = 1,2,\ldots,m ; \quad i = 1,2,\ldots,n \quad \text{and} \quad \sum_{i=1}^{n} w_{i}^k = 1, \quad w_{i}^k > 0, \tag{9}
\]

where \( k \) is the \( k \)-th decision maker, \( i \) is the \( i \)-th alternative.

Considering the \( k \) decision makers’ priority vectors and using the GMM in the aggregation process, the overall collective priority vector \( \mathbf{w}_c \) is computed as shown in (10) below.

\[
\mathbf{w}_c = [w_{1,c}, \ldots, w_{n,c}]^T, \quad \text{where} \quad w_{i}^c = \prod_{k=1}^{m} [w_{i}^k] \tag{10}
\]

4.3.1. Treatment of not equally weighted participants (DMs)

According to (10) DMs are given flat weight when computing the (GM) of priorities. In this model we consider different weights among the DMs’ judgments. Even-though each DM’s priority vector to be considered for aggregation has to conform to the AHP recommended level of \( CR < 0.1 \), the CRs have varying levels. As a result the engine of the model uses the weighted geometric mean method (WGMM) for aggregation process of individual priorities. The two approaches of using the WGMM when computing for the collective priority vector are discussed below.

4.3.1.1. Un-normalized weighted geometric mean method

The un-normalized weighted geometric mean method (UWGMM) is based on computation of GM of the individual priorities without normalization. Following (9) and (10) above the UWGMM introduces the participant’s weight \( \theta_k \) respective of one’s priority vector. Consequently yielding the overall collective priority vector \( \mathbf{w}_c \) whose \( i \)-th element is as indicated in (11) [15, 20].

\[
w_{i}^c = \prod_{k=1}^{m} [w_{i}^k]^{\theta_k} \quad \text{where} \quad \theta_k \quad \text{is the weight of the} \quad k\text{-th participant (DM),} \quad \theta_k > 0; \quad k = 1,2,\ldots,m \tag{11}
\]

4.3.1.2. Normalized weighted geometric mean method

The normalized weighted geometric mean method (NWGMM) is based on computation of GM of the individual priorities and on normalization of the priorities. It yields the overall collective priority vector \( \mathbf{w}_c \) whose \( i \)-th element is computed as in (12) [21, 22].

\[
w_{i}^c = \frac{\prod_{k=1}^{m} [w_{i}^k]^{\theta_k}}{\sum_{i=1}^{n} \prod_{k=1}^{m} [w_{i}^k]^{\theta_k}} \quad ; \quad \text{where} \quad \theta_k \quad \text{is the weight of the} \quad k\text{-th participant,} \quad \theta_k > 0; \quad k = 1,2,\ldots,m \tag{12}
\]

4.4. Computation of the decision makers’ weight (\( \theta_k \))

The method used for computing the decision makers’ weight is based on analysis of the variance computed from one’s submitted judgments forming the PCM \( T \) and its consistent matrix entries \( W \) [24]. We consider this method to be objective because it assigns a weight to a decision maker based on the quality of the PCM one submits. The quality of the PCM is basically determined by the consistency within the judgments from which the variance is ultimately computed.

Having computed the priority vector for each decision maker as indicated in (9) then we can get the decision makers’ corresponding consistence matrices \( W_k^k \quad \forall \quad k = 1,2,\ldots,m \) as;
In addition to the CI value already computed from (7) and used in (8) to ascertain the decision maker’s judgments, we also compute the variance ($\delta_k$) between the judgement entries in $T_k$ and its corresponding consistent entries from $W^k$ as shown below in (15).

$$\delta_k = \sqrt{\frac{\sum_{i=1}^{n} \sum_{j=1}^{n} (t_{ij}^k - w_{ij}^k)^2}{n}}, \; k = 1, 2, \ldots, m$$

The un-normalized weight of the decision maker is obtained as shown in (16) below.

$$\theta_k = \frac{1}{1 + \varepsilon \delta_k}, \; \text{where} \; \varepsilon > 0, \; k = 1, 2, \ldots, m$$

The engine of the model uses the normalized decision maker weight ($\theta_k^*$) which is computed by dividing the individual decision’s maker weight by the sum of the weights of all the group of decision makers ($\sum_{k=1}^{m} \theta_k$) as shown in (16).

$$\theta_k^* = \frac{\theta_k}{(\sum_{k=1}^{m} \theta_k)} \; \text{where} \; \sum_{k=1}^{m} \theta_k^* = 1$$

The normalized DM’s weight is finally used to compute the overall collective priority vector $W_c$ of AIP whose $i^{th}$ element is computed from the NWGMM shown in (17) below.

$$w_{i}^{c} = \frac{\prod_{k=1}^{m} w_{i}^{k} \theta_{k}^{*}}{\sum_{i=1}^{n} \prod_{k=1}^{m} w_{i}^{k} \theta_{k}^{*}}$$

5. Conclusion

The paper presents the mathematical foundations of a four level hierarchical model based on the AHP theory whose objective is to enable the computation of a priority vector for Internet traffic classes (therein establishing the relative importance of the services they deliver to end users) in the context of development.

Although establishing the relative importance among various Internet services is the ultimate solution, it could not be done directly through the model because the number of Internet applications (consequently their corresponding services) continues to grow daily, making it complex to make an objective comparison among ever changing numbers in the effort to establish their relative importance in context of enabling development. Modeling the problem is approached from the point of Internet traffic characteristics that deliver such services since each service delivered over the Internet has a corresponding application that an end user use to achieve ones’ objective. In turn, each application generates a kind of traffic over the internet.

The output of the model is achieved from processing the data obtained from a group of individual decision makers that are independent from each other. The decision makers are weighted in the process of aggregating their priority vectors and the normalized weighted geometric mean method (NWGMM) is used to compute their group priority vector, which is the final output of the model.
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