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Checking consistency for Group-PAHP: a case study of tourism facilities in COVID-19 pandemic

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Abstract

The pandemic situation due COVID-19 highlighted a great vulnerability of tourism systems in the world, defined a scenario characterized by strong uncertainties, unfavorable prospects and widespread fragility (Michie 2020). Our work proposes the use of Multi-Criteria Decision Aiding (MCDA) for analyzing the potentiality of local territory development through the improvement of the tourism facilities. More precisely, we propose the use of the Parsimonious AHP (Abastante et al. 2019) for group choices to analyze a decision-making problem for the improvement of tourism facilities. As the complexity of the decision-making problem and the number of decision-makers grow, there may be problems of consistency of judgments and therefore problems of consistency of the matrices (Brunelli and Cavallo 2020a). Consistency is difficult to achieve in the real situation (Maturo et al. 2005). Our work aims to verify in a 4-step process the errors of consistency that occurs in Pairwise Comparison Matrices with the use of Parsimonious AHP for group choices. Furthermore, we propose a new innovative tool for decision makers to tackle complex problems, with multiple decision categories, a large number of alternatives and several criteria.

Keywords Multi-criteria decision aiding (MCDA) · Parsimonious AHP · Consistency problems · Group choices · Tourism facilities

Highlights

• Parsimonious AHP for group choices is applied in order to improve tourism facilities;

• Consistency of judgments and of the matrices are analysed;

• 4-step process the errors of consistency that occurs in Pairwise Comparison Matrices in Parsimonious AHP are verified;

• An interactive method for finding the most preferred solution is proposed;

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1 Introduction

The Covid-19 pandemic is the cause of a health, economic and social emergency with serious consequences on the growth prospects of many countries and multiple sectors (Chakraborty and Maity 2020). One of the most affected sectors is certainly that of tourism, which is strongly connected to the processes of globalization (Mas-Coma et al., 2020). The pandemic event showed the vulnerability of tourism systems at a global, national and local level, generating a scenario characterized by strong uncertainties, unfavorable prospects and widespread fragility (Michie 2020). Actually, the limitation of travel, the cancellation of flights and the closure of activities in the tourism sector had an immediate impact in terms of reducing the supply and demand for tourism services at national and international level (Bhuiyan et al. 2020). The world scenario has drastically changed, with significant impacts especially in those countries that, like Italy, have always had a strong tourist vocation. The crisis has crossed the entire Italian tourism sector, with very pronounced losses (Aiello et al. 2022). In this work we analyze the potential in terms of local territory development with the improvement of the tourism facilities and a new impulse at pandemic situation; in order to get this of objective we use suitable multicriteria methodologies. The work is developed through the analysis of a specific tourism facilities reality in South Italy. In this sense, Multi-Criteria Decision Aiding (MCDA) is used for analyzing and managing the problems related to the evaluation of the potential of resources in relation to possible development directions. MCDA approach allows to possibly overcome numerous limitations, essentially due to the impossibility of integrating the various information into a single decision-making model (Ishizaka and Siraj 2018). On the other hand, MCDA aims to solve decision-making problems by comparing and evaluating a number of alternatives against several conflicting criteria in order to select the best alternatives. The great value of MCDA techniques in general, but even more so in the tourism sector, is the constructive approach of these techniques in which the definition of the criteria and the identification of alternatives allows the different actors of the decision-making process to confront each other by putting the different needs and different objectives in the field (Kitsios and Grigoroudis 2020).

This paper uses a systematic approach for tourism revival strategic planning with Parsimonious AHP (PAHP) approach (Abastante et al. 2019). MCDA are particularly useful for supporting decision-makers (DMs) in the decision-making process (Ishizaka and Nemery 2013) and in particular, the Parsimonious AHP allows to define a constant dialogue with the DMs avoiding problems common to other MCDA such as for example rank reversal problems (Fedrizzi et al. 2018). MCDA are used to solve several problems (choice, ranking, sorting) and can be used not only for individual choices but also for group choices (Figueira et al., 2005).

Our work proposes a new approach to Parsimonious AHP. We test PAHP for group choices by analyzing two main cases:

- Definition of preferences defined by individual decision makers In this case, we propose methods of aggregation of the judgments in order to obtain the ranking of the alternatives;
- Definition of preferences expressed collectively by a group of individuals. In this case, individuals adopt a majority system to define the ordering of preferences.

In our paper we foresee those different decisional categories participate in the process of choosing and ordering the alternatives; and that in each decisional category the decision-makers express preferences individually or collectively. The partition of the decisional categories by defining two decision-making subsets has as its objective the verification of the ordering of the alternatives taking into account the type of aggregation that is carried out on the judgments (we highlight that in the case in which the preferences are expressed by individual DMs we use the aggregation of judgements by geometric mean; when the preferences are expressed collectively the final judgments is defined with majority system by DMs). In this sense we have to verify if in real situations where preferences are defined collectively by a group of individuals the use of MCDA methods can be useful and if there are problems of coherence on the matrices.

More generally, the aimof this work is to analyse and identify the errors that cause inconsistencies in Pairwise Comparison Matrices (PCMs). We propose, in particular, a construction of PCMs based on 4-step process and a contextual control of the violations of the rules of transitivity and reciprocity that generate inconsistency in the matrices (Cavallo et al. 2015). In this paper we propose an experimentation and analysis of the PCMs, verifying whether consistency problems decrease as information increases. In this sense, we analyze in a real case study how the preferences of decision makers are expressed and we analyze both cases: without any information and with information.

Our work proposes both an innovation from a theoretical and a practical point of view. From a theoretical point of view, our work aims to evaluate the functioning of an MCDA methodology, characterized by a close dialogue with the DM, in group choices. We aim to evaluate, on the basis of preferences expressed individually or by a group of individuals, the cases in which PAHP has fewer problems concerning with the consistency of the matrices. In this sense, our work contributes to enriching the literature on the usefulness of MCDA even when decision-making problems involve several decision-makers or groups of decision-makers proposing particular attention to the control of the consistency of the PCMs. Furthermore, it offers new food for thought on the debate on the consistency of matrices.

The work also contributes from a practical point of view. In fact, the work proposes a new tool for evaluating and ordering alternatives for solving problems for improving tourism facilities. In fact, the methodology we propose really supports the DM who has to solve a complex decision-making problem, made up of a large number of decisional categories, alternatives and criteria.

The paper is developed through the following phases: in Sect. 2 there is a short literature review of MCDA in tourism sector; in Sect. 3 we describe our methodology; therefore, in Sect. 4 we present the application of our methodology that is a case study for improve the tourist facilities; in Sect. 5 we highlight the advantages and innovations of the new approach and we report the principal results of the work; in the last Section we expose the conclusions.

2 Literature Review

The use of MCDA is useful in real contexts (Ishizaka and Siraj, 2018) and helps the DMs to better define the decision-making problem, the alternatives and criteria and to achieve the identified objectives (Ishizaka and Nemery 2013). MCDA is widely adopted in several sectors (see e.g., Fattoruso et al. 2022; Marcarelli and Squillante 2020) and in recent years their use is also expanding in the tourism sector (Ahmad 2016). Several topics in the tourism sector have been managed by MCDA.

Several authors use the MCDA for the identification of Tourism Destination. Carayannis et al. (2018) use MACBETH to evaluate the competitiveness of tourist destinations. Also, Séraphin et al., (2018) use the ELECTRE methods for solve a ranking problem for the evaluation of the performance of a destination. And also, Rashmi et al., (2016) use two different methods AHP with fuzzy approach and TOPSIS Method for solve a ranking problem to identify the best State for Tourism in India. Topic of interest in the tourism sector is the evaluation of ecotourism. In this sense there are several authors; for e.g., KAyA et al. (2013) use PROMETHEE III with fuzzy approach for rank the most appropriate places to promote ecotourism activities in urban areas. Dashti et al. (2013) used AHP with fuzzy approach for identify a rank of the best alternatives to improve the ecotourism in Island of Iran. Another research topic that several authors are interested is tourism policy management; e.g., Liu et al. (2012) used DEMATEL and VIKOR to rank a set of best solutions for an improvement plan for Taiwan's tourism policy.

In the tourism sector very often MCDAs are used to evaluate the quality of the services offered by tourist facilities. Tseng (2011) proposed two different MCDA methods for rank the hot spring hotels in relation of the quality of services. In particular, the author selected a set of criteria useful for the evaluation using the DEMATEL method; He used the fuzzy approach to determine the weights of the criteria and finally to obtain the ranking of the alternatives, the TOPSIS method. Shirouyehzad et al. (2013) use the AHP and DEA to rank the services offered in hotel industry, taking into account their quality. In particular, the authors highlight that the use of MCDAs helps organizations to better identify their strengths than their competitors. Chen et al. (2014) use the AHP for the evaluation of hotel atmosphere, highlights the importance of the decisional support systems for tourism systems. Kurek et al. (2021) integrated the AHP with statistic methods as Principal component analysis for to evaluate the local competitiveness. Racioppi et al. (2015) analysed a complex problem for the territory requalification to improve the attractiveness with the use of AHP. Hsieh et al. (2008) use the ANP method to evaluate the quality of services taking into account their interdependence. The use of the ANP helps the DMs to improve the planning of the services to increase the quality in hot spring hotels. From analysis of the literature, regardless of the specific scope of application, it can be seen that in most cases MCDAs are used to solve ranking problems. Among the main ranking methods are e.g., AHP (Saaty 2004); MACBETH (Bana et al., 2005); PROMETHEE methods (Brans and De Smet 2016); ELECTRE methods (Figueira et al. 2016); Parsimonious ahp (Abastante et al. 2019). Beetween a large number of MCDAs for ranking issues and choosing the best method is not always easy (Ishizaka and Siraj, 2018). For to determinate the most appropriate MCDA method for a specific decision problem is important to analyze the elements that compose it (Greco et al. 2016) or according to Ishizaka and Nemery (2013) identify the most suitable ranking method based on their characteristics as e.g., the Typology of Rank – e.g., complete ranking with score, partial and complete ranking (Ishizaka and Nemery 2013) – or the tools used – e.g., pairwise comparison matrix; preference, indifference and veto thresholds (Fattoruso et al. 2020). In addition, another parameter that helps to select the best MCDA method is to identify whether the choice is of individual or group type (Salo et al. 2021). Based on how you intend to reach the final ranking, the method will have to foresee the aggregation of individual judgments (see e.g., Escobar and Moreno-Jimenéz 2007; List 2012; Wu, 2008) or individual weights (see e.g., Matsatsinis and Samaras 2001; Forman and Peniwati 1998; Zavadskas and Podvezko 2016) or about the choice made by a group in a shared way (see e.g., Saaty 1989; Fedrizzi 1990).

As the complexity of the decision-making problem and the number of decision-makers grow, problems of consistency of judgments and therefore problems of consistency of matrices may arise (Brunelli and Cavallo 2020b). In particular, this happens when pairwise comparison matrices (Pankratova and Nedashkovskaya 2015) are used. Consistency represents the full coherence of the decision maker, and it is difficult to achieve in the real situation (Maturo et al. 2005); the consistency of judgments has been studied by many authors. E.g., Moreno-Jiménez el al., (2008) measure the coherence in the elicitation of judgment through the use of the Preference Structures and Stability Intervals in the AHP. Again, Benítez et al. (2011) propose an interactive feedback process to achieve acceptable levels of consistency in the AHP preference setting process. Lin et al. (2013) measure the level of inconsistency in PCMs through deterministic approaches and statistical or stochastic approaches. Cavallo et al. (2019) analysed the consistency of judgments on multiplicative and additive PCM noting that additive PCM are the ones that more frequently inconsistency.

3 Methodology

We consider a set of alternatives $A = \{a_1, ., a_k \ldots, a_K\}$ and for their evaluation we consider a set of criteria $G = \{g_1, \ldots, g_j, \ldots g_J\}$, therefore $g_j\left(a_k\right)$ define the evaluation of alternative a_k on criterion g_j .

Our methodology aims to rank the alternatives on the basis of the set of criteria, through to the adoption of an MCDA method. Also, we consider a set of decisional categories $C = \{C_1, \ldots, C_e, \ldots, C_E\}$. Each decisional category C_e is composed of two subsets of decision makers:

- Subset $I = \{i_1, ., i_l \ldots, i_L\}$ where i_l represents the generic decision maker and i_L represents the number of DMs in the subset. In this subset, decision makers express their preferences individually;
- Subset $P = \{P_1, ., P_m \ldots, P_M\}$ where P_m represents the generic decision maker and P_M represents the number of DMs in the subset. In this subset, decision makers express their preferences collectively by adopting a majority system.

We assume that each generic decision category C_e is composed of subsets I and P and that:

- $I \subset C_e; i_l \in I \forall i = 1, \ldots, L$
- $P \subset C_e; P_m \in P \forall m = 1, \ldots, M$
- $I \cap P = \varnothing; I \cup P = C_e$
- $I \neq \varnothing; P \neq \varnothing$

We also assume that each decision category C_e has the same weight (Ishizaka and Nemery 2013).

Among the several MCDA methods for ranking problems (Gavade 2014; Odu 2019), we adopt the Parsimonious AHP method as introduced by Abastante et al. (2018). We believe this is the most appropriate method in our decisional problem because it considers several criteria; defines the possibility of consider a large number of alternatives; involves the DMs in every step of the analysis; reduces the number of pairwise comparison beetween the alternatives and avoids rank reversal problems; the decision maker's choice of reference levels makes one more aware of the pairwise comparisons between reference levels and alternatives; reducing the number of inconsistent matrix problems. (Abastante et al. 2019).

In the following, we describe a short overview of the Parsimonious AHP method. The first step of PAHP is the construction of the decisional matrix. The decisional Matrix (A) identifies the direct evaluation $r_j\left(a_k\right)$ of the alternatives a_k respect the criterion g_j considering a scale from 1 to 100. The second phase for the construction of the model is the identification by the DMs defines t_j the reference points $\left(\gamma_{j1},\ldots,\gamma_{jt}\right)$ respect the criterion g_j . According to Corrente et al. (2016) there is a normalization of reference points $u\left(\gamma_{js}\right)$ for all $j=1,\ldots,n$ and for all s=*1,…,* t_j.At this point, we proceeded at the definition of the weights of criteria j and the reference points γ_{js} with the use of the Pairwise Comparison Matrix (Cavallo et al. 2019). The analyst verifies the consistency of the judgments, based on the principle of transitivity and proportionality, and consequently identifies the reliability of the weights obtained by the use of the consistency index $CI=\frac{\lambda_{max}-n}{n-1}$ (see, Saaty 1980); if it is verified the inconsistency of the matrix the analyst discusses the results with the DMs for modify their evaluations (Vincke 1981). Then, the method provides to define the local priority with the use of following linear interpolation:

$$u\left(r_j(\,a_k\,)\right)=u\left(\gamma_{js}\right)+\frac{u\left(\gamma_{js+1}\right)-u\left(\gamma_{js}\right)}{\gamma_{js+1}-\gamma_{js}}\bullet\left(r_j\left(a_k\right)-\gamma_{js}\right)$$

In the last, we obtain the global priority (ω) as aggregation of weights of criteria J and local priority $u\left(r_j\left(a_k\right)\right)$:$\omega=\sum_{j=1}^{J}u\left(r_j\left(a_k\right)\right)\bullet w_j$

In our methodology, the use of PAHP is proposed for group choices by distinguishing two subsets I and P that express their preferences differently. When we consider the subset P in which preferences are expressed collectively, we apply the PAHP methodology as described so far. If we take into consideration the subset I , in which individual preferences are expressed, we introduce in the PAHP method, the aggregation of judgments with the geometric mean (see e.g. Duleba and Moslem 2021).In this sense we define the aggregated matrices for each criterion g_j :

$$\zeta_j=\sqrt[L]{\prod_{l=1}^{L}z_{hql}}$$

and for each reference points γ_{js} for every criterion g_j:

$$\zeta_{\gamma_{js}}=\sqrt[L]{\prod_{l=1}^{L}z_{hql}}$$

Where:

- z_{hql} represents the entries of PCMs in the same position (h, q) with $h = 1, \ldots, n$ and $q = 1, \ldots, n$;
- ζ represents the aggregated matrix;
- l represents the l -th DM;
- L represents the total number of the DMs;

According to Aczél and Saaty (1983) the use of other aggregation technique, as e.g., arithmetic means, is less effective (Krejčí and Stoklasa 2018; Forman and Peniwati 1998) studied the aggregation of individual judgments in AHP, and stated that it is most often carried out using the geometric mean; Saaty (2001) found that geometric means are necessary to integrate the preferences of decision makers in order to perform a group AHP assessment. Lai et al. (2002) proposed four approaches to integrate expert opinions: consensus, vote or compromise, geometric means, and separation of models or actors. Aull-Hyde et al. (2006) suggest that one of the most commonly used aggregation methods is the geometric mean method.

3.1 Consistency checking with errors detection on PCMs: 4-step process

We know that if you consider a set of alternatives $A = \{a_1, ., a_k \ldots, a_K\}$ for the construction on the PCM to each pair of alternatives A_i and A_j a positive real number a_{ij} is assigned which expresses how much A_i is preferred to A_j. In order to verify consistency of the judgments in the PCMs (Brunelli and Cavallo 2020b), the following properties must be verified:

Property 1 Reciprocity. The Reciprocity is expressed as The elements present on the main diagonal are all unitary: This reciprocal relationship arises from the need to guarantee the symmetry of the judgments of importance.

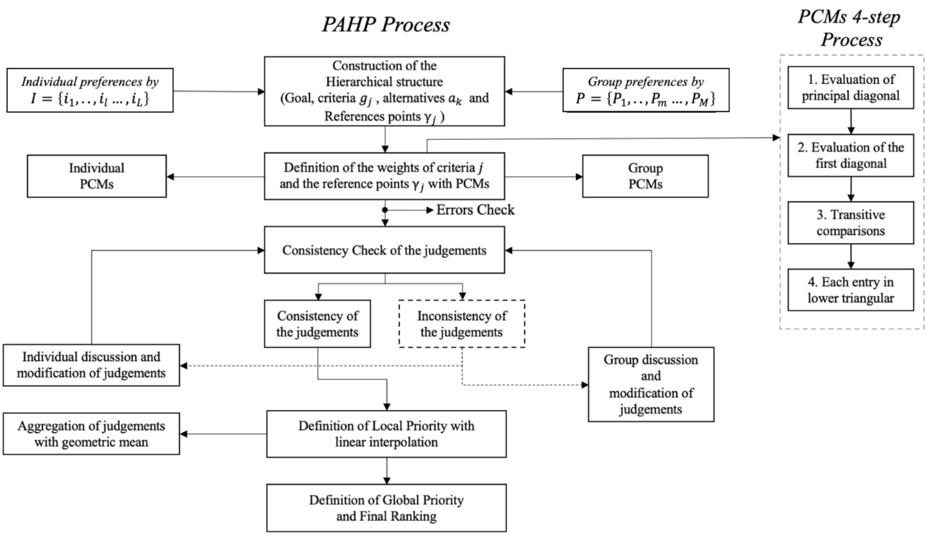

Fig. 1 PCMs with 4-step process for Group-PAHP

Property 2 Transitivity. The transitivity is guaranteed in the matrix. If you consider three alternatives, , with, , and therefore and therefore. And again, the transitivity of judgments provides that .

When properties 1 and 2 are not satisfied, the following errors can occur which cause inconsistency:

- Violation of the transitivity of the relationship of preference: $a_i \succ a_j, a_j \succ a_k$ but $a_i \prec a_k$;
- Violation of proportionality: e.g.,$a_{ij} = 2a_{ik}; a_{ik} = 3a_{kj}; a_{ij} \neq 6a_{kj}$
- Violation of Reciprocity: $a_{ij} \neq \frac{1}{a_{ji}} \forall i, j$; $a_{ii} \neq 1 \forall i$.

For the analysis of the consistency, as show in Fig. 1, our methodology provides to use a construction of PCMs in 4-step process in PAHP for the errors detection which cause inconsistency (Fig. 2).

To build PCMs that don't violate properties 1 and 2, it's possible follow a 4-step (Fig. 2) process that start from principal diagonal and continues in the construction of the upper triangular of the PCM. So, we construct the first diagonal and a this points we can proceed by defining transitive comparisons. Finally, we can deduce each entry in the lower triangular of the PCM (Ishizaka and Lusti 2004).

4 A case study: Applying the methodology to improve hotel facilities in the COVID emergency

The pandemic situation due to COVID-19 has radically changed the way we live life and also the environments we frequent. In particular, the tourism sector has been particularly affected by the pandemic situation (Škare et al. 2021) and very often the accommodation facilities have found themselves facing a profound reorganization of the environments to adapt to the new health and hygiene directives of COVID-19 (Bakar and Rosbi 2020).

The case study regards a resort structure in South Italy. The resort is composed by 242 rooms and offers a very large number of services. Our case study concerns the improvement of the resort common areas based on the new needs due to COVID-19. The main goal is to obtain an evaluation and ordering of all the common areas based on the category of

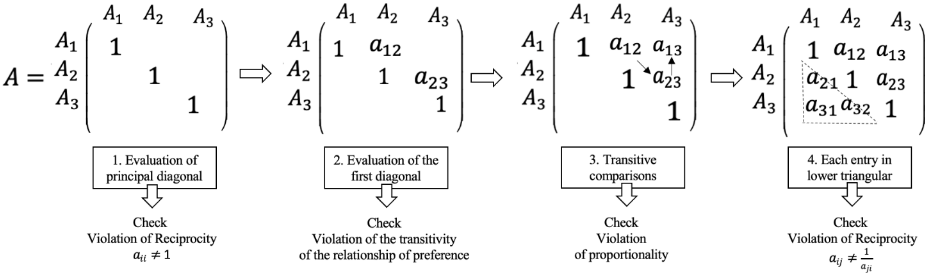

Fig. 2 Errors detection process in PCMs for Group-PAHP

user who frequents the areas. In this sense, the management of the resort wants to improve its areas taking into account the judgments of different categories. In this way they aim to improve not only their own structure but also reputation and safety of the enterprise.

We have selected with the resort management (our DM) the five main decisional categories of users $C = \{C_1, C_2, C_3, C_4, C_5\}$ who frequent the structure:

- Tourists (C_1). We consider in this category all the people who stay in the resort for more than 3 nights;
- Reception staff (C_2). We consider in this category the employees who perform the duties of receptionist, surveillance and porters.
- Catering service staff (C_3). In this category we consider the employees who perform the duties of cooks, waiters and bartenders.
- Housekeeping and floor attendants (C_4). We consider in this category the employees who perform the cleaning service.
- Wellness service staff (C_5). In this category we consider employees who perform services dedicated to body care such as beauticians, physiotherapists, hairdressers and so on.

For each decisional category C_e, the preferences of the DMs are expressed by:

- Decisional subset $I = \{i_1, ., i_{21}\}$ composed by 21 DMs in which each decision maker individually expresses their preferences;
- Decisional subset $P = \{P_1, \ldots, P_{20}\}$ in which there are 20 DMs that define with majority system their preferences.

We defined that any users in decisional category can complete one questionnaire only to prevent respondents having a point of reference when they answer the second survey (Charness, 2012).

Our sample is composed for subset I from 105 users and 100 users for subset P for a total of 205 users. Data collection lasted 3 months, from July 2021 to September 2021. Interviews and focus groups (see e.g., Sim and Waterfield 2019) were used to structure the analysis. The interviews were based on an open, wide-ranging protocol (Czarniaswka, 2004) provided one week before the first interview. For the construction of the decisional problem, we consider 4 criteria G=$\{g_1, g_2, g_{3,}g_4\}$ described below:

- Area Safety (g_1): we consider safety in terms of compliance with the regulations to combat the covid 19 epidemic, therefore the correct use of masks by staff and guests in general; greenpass control for anyone entering the resort; and all other useful measures to try to ensure reliability and trust in the structure.
- Organization of Places (g_2): understood as the management of common spaces: access to these areas must be limited; employees and customers must try to stay there for the time strictly necessary, in order to reduce the simultaneous presence of more people and thus avoid forms of gathering.
- Services Quality (g_3): Quality is a theoretical construct that cannot be measured directly, it is a complex concept, which is made up of numerous dimensions; it is certainly the most competitive advantage of a tourism company which is directly linked to

the satisfaction of guests who have received tourism products and services. In our case we have considered for this criterion: the provision of the service in complete safety and without risks and doubts; in addition to accessibility, meaning that the service can be used without obstacles or difficulties. Another important precaution to be adopted to guarantee quality is that linked to the ventilation of the rooms and their cleaning and sanitation: in fact, in order to maintain adequate sanitary conditions, the rooms are equipped with natural or forced ventilation systems, cleaned and sanitized.

- Adequacy of information on Covid-19 Behavioral Rules (g_4): individuals are informed correctly and in an understandable language. misinformation in this delicate phase of our life can be a problem, all staff and customers must have all the information available to allow compliance with the rules and protocol envisaged for Covid-19. The attention of workers to compliance with the measures implemented may be the subject of specific information, but also horizontal and vertical signs in the vicinity of the aforementioned areas.

And we consider a set of 14 alternatives A=$\{a_1, \ldots, a_{14}\}$ as following: snack area (a_1); reception (a_2); conference rooms (a_3); ristorantes (a_4); wellness area (a_5); bar (a_6); breakfast buffet area (a_7); children's area (a_8); security front office (a_9); gym (a_{10}); service (a_{11}); swimming pools (a_{12}); offices (a_{13}); Waiting rooms (a_{14}).

Table 1 Decisional Matrix (A)

	$\boldsymbol{g}_1$	$\boldsymbol{g}_2$	$\boldsymbol{g}_3$	$\boldsymbol{g}_4$
$\boldsymbol{a}_1$	24	24	24	22
$\boldsymbol{a}_2$	26	20	20	21
$\boldsymbol{a}_3$	29	30	25	23
$\boldsymbol{a}_4$	30	29	24	23
$\boldsymbol{a}_5$	22	26	24	23
$\boldsymbol{a}_6$	20	24	20	16
$\boldsymbol{a}_7$	20	27	20	16
$\boldsymbol{a}_8$	22	19	29	15
$\boldsymbol{a}_9$	24	26	25	17
$\boldsymbol{a}_{10}$	25	24	30	21
$\boldsymbol{a}_{11}$	16	22	16	26
$\boldsymbol{a}_{12}$	20	24	20	26
$\boldsymbol{a}_{13}$	22	22	15	22
$\boldsymbol{a}_{14}$	16	23	24	24

Table 2 Reference points γ_{js} for decisional category C_1

	γ_{j1}	γ_{j2}	γ_{j3}	γ_{j4}
$\boldsymbol{g}_1$	14,8	20,8	24,6	29,9
$\boldsymbol{g}_2$	14,9	20,9	24,8	29,8
$\boldsymbol{g}_3$	14,9	20,6	24,8	30,0
$\boldsymbol{g}_4$	14,8	20,8	24,9	30,0

We report in Table 1 the decisional matrix constructed by the help of the DM. The DM use a scale from 1 to 30 for the definition of the evaluation $r_j(a_k)$ of the alternatives a_k respect the criterion g_j.

At this point, we have shown the decision matrix (A) to each decisional category C_e and with a focus group (see, e.g., Bayraktaroğlu and Özgen 2008), we asked each decision category to identify the reference points γ_{js} respect the criterion g_j. In Table 2 we reported the reference points γ_{js} defined by decisional category C_1.

After the definition of reference points γ_{js}, we moved on to the second step of the PAHP: the definition of preferences and the construction of PCMs for the evaluation of criteria and reference points.

For this aim, we submitted to categories C_1 and C_2 - both for subsets I and P - the questionnaire for the construction of the PCMs without any indication on properties 1 and 2 (defined in Sect. 3) which guarantee the consistency of the matrices.

Instead, we showed to categories C_3, C_4 and C_5 - both to subsets I and P - before submitting the questionnaire for the construction of the PCMs, the 4-step process that shows how a PCM is built and we have described the properties defined in Sect. 3.

We asked to each DM i_l, to identify with the use of the PCM (Cavallo et al. 2019) the evaluation of criterion g_j and the reference points γ_{js}.

The preference is expressed through a verbal judgment for each criterion g_j and for each reference points γ_{js}, through the Saaty scale (Saaty 1980).

We verified the consistency of the judgments, based on the principle of transitivity and proportionality (Cavallo et al. 2016), ascertaining the reliability of the weights obtained through the consistency index CI. To assess whether the judgments are consistent or not, the AHP method therefore provides for the comparison of the consistency index with the Random Index (Ishizaka 2019). So, we analysed the Consistency Ratio (CR) $CR = CI/RI$ as a measure of inconsistency independent of the order of the matrix. If $CI \leq 0.1$ of RI then the matrix and its comparisons are considered acceptable (Lukinskiy et al. 2021). From this analysis, we verified in several case that the value of CI exceeds a threshold equal to 10% of RI, the deviation from the condition of consistency is considered unacceptable and therefore the judgments had to be revised to increase their consistency and fall within the admissibility rang (Cavallo 2017). In cases of inconsistency, we reviewed the judgments with the individual decision-makers highlighting where the judgments did not respect the principles of transitivity of preference and indifference (Vincke 1981). The guided decision makers then modified their evaluations obtaining the monotony of the opinions expressed with respect to the reference levels (Abastante et al. 2019).

At this point, we applied the aggregation formula shown in session 3 to obtain the aggregated matrices of judgments ζ_j and $\zeta_{\gamma_{js}}$ for every decisional category C_e. We reported the

Table 3 Aggregated matrix ζ_j (C_1)

	$\boldsymbol{g}_1$	$\boldsymbol{g}_2$	$\boldsymbol{g}_3$	$\boldsymbol{g}_4$	w_J
$\boldsymbol{g}_1$	1	0,00072	0,00071	0,00071	0,152
$\boldsymbol{g}_2$		1	0,00071	0,00071	0,235
$\boldsymbol{g}_3$			1	0,00072	0,248
$\boldsymbol{g}_4$				1	0,364
				CI	**0,06**

aggregated matrices $\zeta_j(C_1)$ in Table 3 and $\zeta_{\gamma_{1s}}(C_1)$ in Table 4. The weights w_J are calculated using the eigenvalue method (Ishizaka 2019).

Table 4 Aggregated matrix $\zeta_{\gamma_{1s}}(C_1)$ for criterion g_1

	γ_{11}	γ_{12}	γ_{13}	γ_{14}	$u(\gamma_{js})$
γ_{11}	1	0,32729	0,16692	0,169554	0,059
γ_{12}		1	0,31528	0,32307	0,142
γ_{13}			1	0,603881	0,387
γ_{14}				1	0,413
				CI	0,00927

Table 5 Evaluation of criteria g_J by subset P for C_1

	g_1	g_2	g_3	g_4	w_J
g_1	1	1/3	1/9	1/9	0,04
g_2		1	1/3	1/9	0,09
g_3			1	1/3	0,26
g_4				1	0,611
				CI	0,06

Table 6 Evaluation of reference points γ_{js} for criterion g_1 by subset P for C_1

	γ_{11}	γ_{12}	γ_{13}	γ_{14}	$u(\gamma_{js})$
γ_{11}	1	1/3	1/6	1/6	0,059
γ_{12}		1	1/3	1/3	0,142
γ_{13}			1	1/2	0,387
γ_{14}				1	0,413
				CI	0,00927

Table 7 Local and global priority for subset I

	$u(r_1(a_k))$	$u(r_2(a_k))$	$u(r_3(a_k))$	$u(r_4(a_k))$	Global Priority
a_1	0,348	0,150	0,174	0,171	**0,193**
a_2	0,477	0,137	0,133	0,165	**0,198**
a_3	0,408	0,609	0,182	0,176	**0,315**
a_4	0,413	0,522	0,174	0,176	**0,293**
a_5	0,158	0,156	0,174	0,176	**0,168**
a_6	0,130	0,150	0,133	0,088	**0,120**
a_7	0,130	0,347	0,133	0,088	**0,167**
a_8	0,158	0,132	0,575	0,073	**0,224**
a_9	0,348	0,156	0,199	0,104	**0,177**
a_{10}	0,412	0,150	0,669	0,165	**0,324**
a_{11}	0,075	0,145	0,060	0,286	**0,164**
a_{12}	0,130	0,150	0,133	0,286	**0,192**
a_{13}	0,158	0,145	0,041	0,413	**0,219**
a_{14}	0,075	0,147	0,174	0,182	**0,155**

With a focus group, at the same time, we asked to the members of subset P to evaluate, with pairwise comparison matrix, criteria g_J and the reference points γ_{js}. The preferences were expressed with a majority system with the use of the Saaty scale. Again, we used the eigenvalue method (Ishizaka 2019) to calculate the weights w_J. In this case, from the analysis of consistency of the judgments we obtained the $CI \leq 0.1$ of RI then the matrix and its comparisons are considered acceptable. In Table 5 we show the evaluation of criteria g_J and in Table 6 the evaluation of the reference points γ_{js} respect the criterion g_1 expressed by the users in the subset P.

We define with the use of linear interpolation formula, shown in Sect. 3, the local priorities and the global priorities by aggregating, according to all the criteria $g_i \in G$, the weighted local priorities for each alternative a_k. We show the local and global priority for the DMs of subset I in Table 7 and for the DMs of subset P in Table 8.

4.1 Results and discussion

The application of our approach for the improvement of tourism facilities has got two main results. The first result concerns the detection of the most common errors committed in the construction of the PCMs and the consequent problems of consistency of the matrices.

In particular, our analysis shows that when decision-makers do not receive suitable information on how to make comparisons in pairs and therefore build a PCM, they commit more violations of the rules of transitivity and reciprocity.

As shown in Table 9, in many cases DMs frequently commit violations of the transitivity rules. In the case study we analyse what happens depending on whether or not individuals have information when making decisions. Specifically, two decision categories C_1 and C_2 do not receive any information when building the PCMs, while the decision categories C_3, C_4, C_5, are informed of the properties 1 and 2 and the 4-step process for building the PCMs.

It can be observed that in the absence of information, when preferences are expressed individually there is a violation of the transitivity of the relationship of preference of about 32%, violation of proportionality for about 38% and violation of reciprocity ($a_{ij} \neq \frac{1}{a_{ji}}$) with

Table 8 Local and global priority for subset P

	$\boldsymbol{u}\,(\boldsymbol{r}_1(\boldsymbol{a}_k))$	$\boldsymbol{u}\,(\boldsymbol{r}_2(\boldsymbol{a}_k))$	$\boldsymbol{u}\,(\boldsymbol{r}_3(\boldsymbol{a}_k))$	$\boldsymbol{u}\,(\boldsymbol{r}_4(\boldsymbol{a}_k))$	Global Priority
$\boldsymbol{a}_1$	0,271	0,242	0,242	0,177	**0,203**
$\boldsymbol{a}_2$	0,295	0,164	0,088	0,135	**0,132**
$\boldsymbol{a}_3$	0,351	0,512	0,286	0,220	**0,267**
$\boldsymbol{a}_4$	0,368	0,463	0,242	0,220	**0,252**
$\boldsymbol{a}_5$	0,253	0,281	0,242	0,220	**0,232**
$\boldsymbol{a}_6$	0,217	0,242	0,088	0,059	**0,089**
$\boldsymbol{a}_7$	0,217	0,366	0,088	0,059	**0,100**
$\boldsymbol{a}_8$	0,253	0,143	0,528	0,045	**0,188**
$\boldsymbol{a}_9$	0,271	0,281	0,289	0,074	**0,156**
$\boldsymbol{a}_{10}$	0,283	0,242	0,588	0,135	**0,268**
$\boldsymbol{a}_{11}$	0,146	0,206	0,051	0,349	**0,251**
$\boldsymbol{a}_{12}$	0,217	0,242	0,088	0,349	**0,266**
$\boldsymbol{a}_{13}$	0,253	0,206	0,042	0,354	**0,255**
$\boldsymbol{a}_{14}$	0,146	0,223	0,242	0,262	**0,248**

Table 9 Errors Detection in PCMs with and without 4-step process

	PCMs without 4-step process (C_1 and C_2)		PCMs with 4-step process (C_3, C_4, and C_5)	
	Subset I	Subset P	Subset I	Subset P
Violation of Reciprocity $a_{ii} \neq 1$	8 (3,81%)	-	-	-
Violation of the transitivity of the relationship of preference	68 (32,39%)	2 (20%)	31 (9,85%)	1 (6,66%)
Violation of proportionality	80 (38,09%)	3 (30%)	98 (31,10%)	2 (13,34%)
Violation of Reciprocity: $a_{ij} \neq \frac{1}{a_{ji}}$	38 (18,09%)	1 (10%)	14 (4,45%)	-
No violation	16 (7,62%)	4 (40%)	172 (54,60%)	12 (80%)
TOTAL	210	10	315	15

about 18%. Again, in the absence of information, when preferences are expressed collectively, there is a violation of the transitivity of the preference ratio for about 20%, violation of proportionality for about 30% and violation of reciprocity for about 10%. Only 7% in subset I and 40% in subset P do not make mistakes in the process of creating PCMs.

Instead, when the decision makers (categories C_3, C_4, C_5) receive information, the number of errors and therefore of violations in terms of transitivity and reciprocity improves significantly. In fact, when preferences are expressed individually, there is a violation of the transitivity of the preference ratio for about 10%, a violation of proportionality for about 31% and a violation of reciprocity for about 4%. Whle when preferences are expressed collectively, there is a violation of the transitivity of the preference ratio for about 6%, violation of proportionality for about 13% and no violation of reciprocity. Furthermore, in the presence of information, 54% in subset I and 80% in subset P make no mistakes in the process

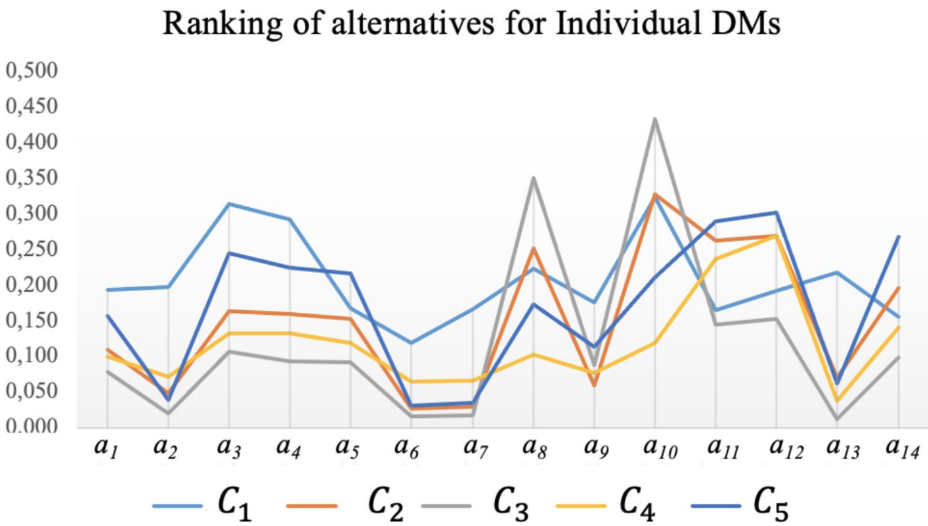

Fig. 3 Ranking of alternatives for Subset I

of creating the PCMs. Finally, it should be noted that in both cases analyzed, the individuals of subset P commit fewer errors and therefore fewer violations of the rules necessary for the consistency of the PCMs.

By the results obtained it is possible to define that when the decision makers are informed about the rules of transitivity and reciprocity and use the 4-step process for the construction of the PCMs, there are fewer violations of properties 1 and 2. The use of the 4-step process defines the first diagonal as the starting point (Fig. 2) in this way it is possible to obtain the other comparisons in pairs in the upper triangular of the matrix by multiplication rather than by division (Ishizaka and Lusti 2004). Furthermore, problems of compromising the – psychological –independence of the comparisons are avoided.

The second result concerns the ranking of alternatives by category and typology of decision maker. As show in Fig. 3:

In Fig. 3, we report the ranking of the alternatives that is obtained when the DMs individually express their preferences. In detail, it can be seen that the most preferred alternatives are: conference rooms (a_3); children's area (a_8); gym (a_{10}). Instead, the alternatives that require an enhancement of the areas and a reorganization are: reception (a_2); bar (a_6); breakfast buffet area (a_7); offices (a_{13}).

In Fig. 4, we report the ranking of alternatives when preferences are expressed collectively. Among the preferred alternatives are: conference rooms (a_3); ristorants (a_4); gym (a_{10}). Among the least preferred, however, there are: reception (a_2); bar (a_6).

5 Conclusions

The aim of this work is to analyze with a 4-step process the errors that violate the axioms of transitivity and reciprocity in pairwise comparison matrices.

Our work analyzes the preferences expressed by 5 different decision-making categories in which two main decisional subsets are distinguished: the first in which preferences are

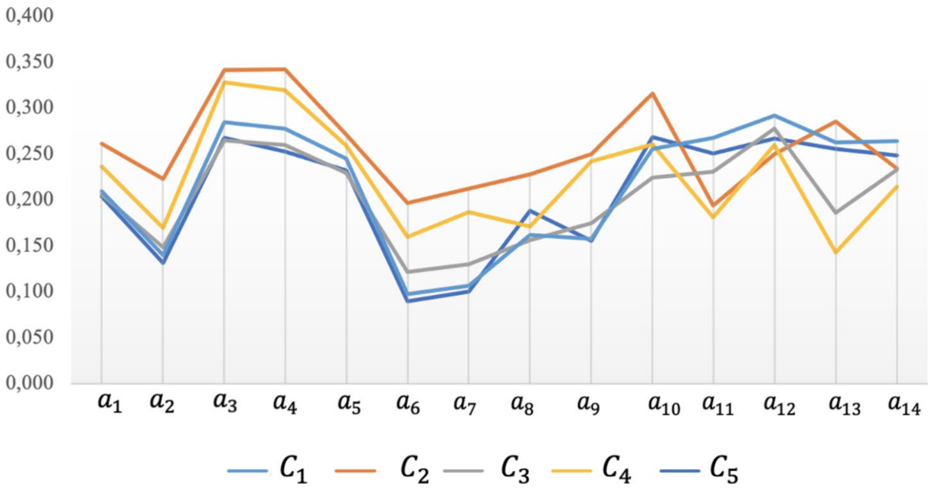

Fig. 4 Ranking of alternatives for Subset P

defined by individual decision makers and the second in which preferences are expressed collectively by a group of individuals. We verify how preferences are expressed based on the degree of information on the elements that generate the inconsistency of the matrices and on the 4-step process to build coherent PCMs.

In particular, we analyse this aspect on the PCMs of Parsimonious AHP method used for group choices in tourist structures. The method used is an interactive method and involves the decision maker throughout the construction of the method. In fact, one of the characteristics of the Parsimonious AHP is the comparison with the decision makers on the coherence of the judgments and therefore an accurate analysis of the consistency of the matrices.

In our work it emerges that as the degree of information on the properties that characterize PCMs and the reasons that determine consistency problems increase, a greater awareness of DMs in expressing their preferences is determinate. In this sense, our work shows that as information increases, cases of inconsistency in PCMs decrease. Furthermore, it appears that there are fewer consistency problems when decision makers express their preferences in groups.In future works we intend to analyze consistency problems in the context of social choices based on the types of PCMs (e.g., additive and fuzzy) used.

Declarations of interest None.

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