Consensus in prioritizing river rehabilitation projects through the integration of social, economic and landscape indicators

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ABSTRACT

Selecting a river rehabilitation project is a complex decision which should address social, economic and landscape indicators. The rehabilitation project becomes even more complicated if the city qualifies for inscription on the UNESCO World Heritage List. Tangible and intangible factors must be assessed to take into account cultural and natural heritage, water flow, river naturalization, interaction of water stream, construction costs and operational and maintenance costs. The proposed method is a hybrid model combining Delphi, Analytical Hierarchy Process and VIKOR technique. This hybrid model has been applied to the historic walled town of Cuenca and the Huecar river. The objective of the selected rehabilitation project must be the optimal integration of the river in the townscape. The indicators most valued by the panelists have been cultural heritage and river naturalization with 28% and 25% respectively. As a result, the trapezoidal cross section has achieved an acceptable advantage and stability over the modified triangular cross section, valued as second.

1. Introduction

In the United Nations World Water Development Report 2015, the Director-General of UNESCO Irina Bokova stated that water is inextricably linked to the development of all societies and cultures and therefore placing considerable pressure on water resources (UN-

Water, 2015). Within this context, restoration of rivers has become a key policy objective in many countries around the world (Becker et al., 2014). River rehabilitation evaluation should be based not only on criteria of economic efficiency but also on broader landscape, cultural and social indicators. Decision making processes in river rehabilitation projects are complex due to the uncertainty about the benefits and conflicting goals. Therefore, river rehabilitation decisions should be undertaken based on a systematic and comprehensive procedure with sufficient consensus and transparency to avoid lack of acceptance. This gets even more complicated if the city qualifies for inscription on the UNESCO World Heritage List (WHL). UNESCO World Heritage Convention qualifies for inscription on the WHL on the basis of six cultural and four natural criteria (UNESCO, 2006). To be included on the WHL, sites must be of outstanding universal value and meet at least one of ten selection criteria. In our case, the historic walled town of Cuenca and the Huecar river were qualified for inscription on the WHL on the basis of criteria iii, iv and v. These criteria focus on: bearing a unique or at least exceptional testimony to a cultural traditional; being an outstanding example of building, architectural or landscape which illustrates a significant stage in human history; and being an outstanding example of traditional human settlement, land-use which is representative of a culture or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change (UNESCO, 1995). A key factor to accomplish these criteria has been the integration between the upper town medieval fortress and the Huecar river and its surrounding landscape. In addition, the river rehabilitation receives nowadays more attention due to the public increasing awareness on its environmental degradation (EU Directive 2000; Tanago et al., 2012). Therefore, the indicators involved in the development of this project must include environmental, architectural, social, cultural and landscape factors (Canto-Perello and Curiel-Esparza, 2006; Akiner and Akiner, 2010; Matthews et al., 2015). The rehabilitation project is complex and requires a multidisciplinary panel of experts.

Hybrid models combining the Analytical Hierarchy Process (AHP) with other techniques using panels of experts have been successfully applied in environmental engineering. Hu et al. (2012) proposes an evaluation framework of sustainable performance applying Fuzzy and AHP to implement product service systems. Liaghat et al. (2013) have integrated Weighted Linear Combination (WLC) as maps overlay of relevant indicators with AHP to analyze coastal tourism sites in Port Dickson district of Malaysia. Turskis et al. (2013) have studied the condition of the built and human environment through efficient decision making using AHP and ARAS-G techniques in renovation supported by multiple attribute evaluation. Wey and Hsu (2014) promote stakeholder engagement applying Delphi and AHP procedures to community development planning in the City of Irvine in the United States. Song et al. (2015) have proposed a hybrid method combining Delphi survey with GIS and Monte Carlo simulation to evaluate ecological vulnerability. Shang et al. (2015) have proposed an evaluation index system for Green Mine performance of China combining Fuzzy and AHP. Mousavi et al. (2015) have combined WLC and AHP for the identification and the prioritization of the most preferred areas for the establishment of corals artificial reefs. Canto-Perello et al. (2016) have developed an A'WOT hybrid method combining SWOT technique and AHP to promote the sustainable use of the urban underground space. Jiang et al. (2016) have studied healthy urban streams of the Suzhou creek corridor in Shanghai applying AHP with GIS data analysis and GIS space technology. Kamaruzzaman et al. (2016) have confirmed the Delphi method as the most applicable technique to develop comprehensive building environmental assessments.

This paper will focus on the selection of a rehabilitation project using a decision support system which will be a hybrid model combining the AHP with the Delphi method and the VIKOR technique (Curiel-Esparza et al., 2014; Martin-Utrillas et al., 2015a; Mardani et al., 2016). It is expected from the hybrid model to achieve consensus on a complex decision among all the relevant stakeholders, with different points of views, sometimes opposed to each other. The hypothesis is whether this consensus may be achieved by a structured procedure integrating social, economic and landscape indicators. In addition, the compromise solution must also verify the conditions of acceptable advantage and stability to guarantee the maximum group utility and the minimum of disapproval The main strength is the ability to deal with tangible and intangible indicators. The proposed hybrid model develops pairwise comparison judgments from a panel of experts that are used to implement overall priorities for ranking the indicators and projects. The Delphi technique is well suited as a method for consensus-building by using a series of questionnaires to collect data from panelists (Gracht, 2012). The Delphi method has facilitated an efficient panel survey. Secondly, the AHP method has been capable of dealing with incommensurable criteria based on paired comparison from experts' judgment (Saaty, 2012a; Li et al., 2014; Wang and Xu, 2015). And finally, the VIKOR method has found a compromise solution for this decision problem that is the closest to the ideal (Opricovic and Tzeng, 2007; Liou et al., 2011). The present study sought to address existing literature gaps by: selecting a river rehabilitation project taking into account social, economic and landscape indicators; assessing tangible and intangible factors; reaching consensus among the different stakeholders; and ensuring the optimal integration of the river in the townscape. The rehabilitation projects have been evaluated according to all established indicators. And the achieved compromise solution has provided a maximum utility of the majority, and a minimum individual regret of the opponent in overall.

2. Methodology

The proposed method is a hybrid model combining Delphi, AHP, and VIKOR techniques. The Delphi method is an anonymously experts' foresight procedure. It is suitable for achieving consensus applying a series of questionnaires (Roubelat, 2011). This procedure gathers the point of views from the panelists. The panel consists of ten experts with recognized competence in urban planning and environmental engineering. An anonymous open-ended survey is sent to the panelists, who answer it including new strategies or indicators they think are pertinent to the analysis (Norouzian-Maleki et al., 2015). Afterwards, there is a feedback to reach consensus resending these data to the panelists in order to reconsider their answers. This feedback procedure with the aim of building consensus defines the three levels hierarchy shown in Fig. 1. AHP uses this hierarchy structure to analyze the indicators and the river rehabilitation projects relations among them and the objective, facilitating the comparisons by the panelists. The upper level shows the goal to be achieved. The indicators to be studied are depicted in the second level. And, the lower level of the hierarchy structure consists of the river rehabilitation projects to be analyzed among the panelists. The AHP technique uses paired comparison judgments from the panelists (Saaty, 2012b). These paired comparisons are used to evaluate the relative priority of the indicators. In addition, the consistency of the panelists' judgments has been analyzed to avoid random answers. Finally, the VIKOR procedure achieves the consensus rehabilitation project in complex problems involving different indicators. Two parameters will be evaluated for each of the rehabilitation projects: utility of the majority and individual reject (Opricovic, 2011). These parameters will be gathered in a consensus strategy to reach the optimal solution. The compromise river rehabilitation project is the one which achieves the maximum utility and the minimum regret. In addition, the compromise river rehabilitation project must satisfy the conditions of acceptable advantage and acceptable stability.

2.1. Hierarchy structure for selecting a river rehabilitation project

According to the Delphi method, the first questionnaire sent to the panelists has been used to choose main indicators and a set of projects. The interaction among the experts has been achieved with anonymous feedback. Afterwards, the AHP has been used to reduce the overall decision into smaller decision problems. The indicators and solutions agreed by the panelists as being of low importance have been removed (Curiel-Esparza et al., 2015). The adequate selection of indicators has been a key factor to lead to transparency in this procedure as discussed later on. From the first survey, the following indicators have been proposed:

- Cultural Heritage (CUH): This indicator has taken into account all aspects relative to ancient constructions as medieval walls, old bridges and traditional buildings, even the townscape and singular views integrating historical aspects and landscaping (Nagi, 2012; Brida et al., 2013; Zhang et al, 2015).

- Natural Heritage (NAH): This indicator has evaluated the historical environment and natural values. For example, using local materials, developing autochthonous vegetation, creation of water mirrors and rupture of linearity have been analyzed (Luderitz et al., 2011; Hale et al., 2014; Lee and Hsieh, 2016).

- Water Flow (WAF): This indicator has focused on the different regimes of water movement mainly based on the slope, wet section, rugosity and natural flow (Valiani and Caleffi, 2009; Mejia and Reed, 2011).

- River Naturalization (RIN): This indicator has evaluated the actions needed for enhancing the riparian and aquatic vegetation, the river ecosystem and the physicochemical characteristics of the high mountain water (Luderitz, 2011). Riparian ecosystems are functionally connected to upstream and downstream ecosystems and are laterally connected to upland and aquatic ecosystems (Mitsch and Jorgensen, 2004).

- Interaction of Water Stream (IWS): This indicator has addressed the effects of sounds from water based on the perception of acoustic environments of water sound (Carles et al., 1999), soundscape enhancement and its contribution in the assessment of urban soundscapes (Radsten-Ekman et al., 2013; Jeon et al., 2012; Galbrun and Ali, 2013). The impact of urban heat island together with the effects of water temperature in the riverbanks and surroundings have been also considered as factors in this indicator (Hathway and Sharples, 2012).

- Construction Costs (COC): This indicator has taken into account the costs of building, installation of electromechanical machinery and gardening (Martin-Utrillas et al., 2015b).

- Operational and Maintenance Costs (OMC): This indicator has focused on the operation, maintenance and management of the infrastructure (Canto-Perello et al., 2009).

The objective of the rehabilitation project must be to restore the river ecosystem to a more natural state. To this end, the experts have chosen six possible solutions from a set of symmetrical cross sections as shown in Fig. 2. And the hierarchy structure for the decision support system has been constructed as depicted in Fig. 1.

2.2. Obtaining priorities for the studied rehabilitation projects

A second questionnaire has been sent to the panel of experts in order to determine the priority of the indicators using a 1-9 preference scale as shown in Table 1. Each panelist has performed a pairwise comparison to state its preference for each indicator, marking its selection on the Delphi questionnaire itself (see Table 1). Higher values correspond to a higher preference of one of the paired indicators presented over the other. If the panelist chooses the first indicator over the second, the number used is the corresponding integer. However, if the panelist prefers the second indicator over the first one, the inverse of the integer selected will be applied. As result of this survey, the pairwise comparison matrix for the indicators has been obtained. For the aggregation of individual judgments, the geometric mean method has been used as follows:

$$\mathrm{rp}_{\mathrm{ij}} = \prod_{\mathrm{k}=1}^{10} \left(\mathrm{rp}_{\mathrm{ij}}^{(\mathrm{k})}\right)^{1/\mathrm{k}}. \quad (1)$$

With these values, the reciprocal 7-by-7 rehabilitation project matrix (RP) is constructed. RP is the pairwise comparison matrix for indicators, the principal eigenvector of RP is the priority vector ω. In order to find this priority vector, the following linear system must be solved:

$$RP\ \omega = \lambda\ \omega \rightarrow det(RP - \lambda I) = 0 \quad (2)$$

As result, the dominant eigenvalue λ_{max} and the priority vector ω of the indicators are obtained:

$$\lambda_{max} = 7.1104 \quad (3)$$
$$\omega = [0.2800 \quad 0.1405 \quad 0.0594 \quad 0.2478 \quad 0.1805 \quad 0.0287 \quad 0.0632] \quad (4)$$

In addition, one of AHP´s advantages is to measure inconsistency in the survey process. That is, sometimes experts are not able to express consistent preferences when comparing several criteria. To address this possibility, the AHP method measures the inconsistency of the pairwise comparison matrix and sets a consistency threshold which should not be exceeded in order to guarantee the procedure (Saaty, 2012b). The consistency ratio (CR) is used as the main indicator for ranking consistency. A CR value of 0.1 or below is considered acceptable for order of matrix equal or larger than five. Any higher score indicates that the judgments need re-examination. CR is calculated by dividing the consistency index (CI) by the random consistency index (RCI) as follows:

$$CR = \frac{CI}{RCI} \quad (5)$$

The dominant eigenvalue λ_{max} is needed to calculate the CI as follows:

$$\mathrm{CI} = \frac{(\lambda_{\max} - n)}{(n-1)} \quad (6)$$

Where n is the number of evaluated indicators. To obtain a consistent matrix as shown in Table 2, judgments have been reviewed and improved when the CR has been over the threshold.

Afterwards, the experts have performed a pairwise comparison to determine its preference among the rehabilitation projects for each indicator via a third survey. The six cross sections under study are illustrated in Fig. 2. The pairwise comparison matrices have been obtained for each indicator and for all cross sections using judgments assessed by each panelist. As in the previous section, the eigenvector method has been used to determine the priority vector. In addition, a consistency analysis has been undertaken as depicted in Table 3. Finally, the decision matrix with the priority vectors of the different cross sections with respect to each indicator has been constructed as shown in Table 4.

3. Achieving a compromise solution with VIKOR method

The VIKOR method has been applied in order to ensure consensus on the rehabilitation project selected (Opricovic, 2009). This procedure ranks the alternatives measuring the closeness of the enhancements to the ideal rehabilitation project (Tavakkoli-Moghaddam and Mousave, 2011; Fallahpour and Moghassem, 2012). The alternative selected reaches a maximum group utility of the majority and a minimum individual regret. To this end, the six rehabilitation projects have been evaluated according to the seven indicators previously studied. Finally, the two conditions of acceptable advantage and stability have been assessed. The technique sorts the projects by the values of Q, obtained from the matrix of the eigenvectors shown in Table 4. For each indicator, the values of f_j^* and f_j^- are calculated. These values are the maximum and the minimum values obtained assessing the projects, and correspond with the best and the worst output for the given indicators as follows:

$$f_j^* = max_i\{x_{ij}\} \tag{7}$$

$$f_j^- = min_i\{x_{ij}\} \tag{8}$$

The values of f_j^* and f_j^- are depicted in Table 5. The best rehabilitation project has been obtained using the compromise ranking procedure. This procedure ranks concordance using the parameter S (group utility of the majority) and disagreement through the parameter R (disapproval of the opponent). These values are given by the following equations:

$$S_i = \sum_{j=1}^{n} w_j \frac{f_j^* - x_{ij}}{f_j^* - f_j^-} \tag{9}$$

$$R_i = max_j w_j \frac{f_j^* - x_{ij}}{f_j^* - f_j^-} \tag{10}$$

Where w_j is the priority of each indicator.

Finally, the Q_i values are computed as follows:

$$Q_j = \gamma \frac{S_i - S^*}{S^- - S^*} + (1-\gamma)\frac{R_i - R^*}{R^- - R^*} \quad (11)$$

where,

$$S^* = min_i S_i \quad (12)$$
$$S^- = max_i S_i \quad (13)$$
$$R^* = min_i R_i \quad (14)$$
$$R^- = max_i R_i. \quad (15)$$

The value of γ = 0.5 is applied as a weight for a consensus strategy (Curiel-Esparza et al., 2016). The results are shown in Table 5. Hereafter, the cross sections are classified by S, R and Q values as depicted in Table 6. In addition, the two conditions of acceptable advantage and stability are also satisfied as shown below.

- Acceptable advantage: The difference between PS and MS rehabilitation projects satisfies:

  $$Q(MS) - Q(PS) = 0.4798 \geq DQ \quad (16)$$

  where

  $$DQ = \frac{1}{J-1} = 0.2 \quad (17)$$

- Acceptable stability: The PS cross section is the best classified by Q and also by S and R as shown in Table 6.

4. Discussion of results

The river rehabilitation project has been selected using the experience of the panel of experts throughout questionnaires as shown in Table 1. These questionnaires have been managed using the Delphi method. The priorities of the indicators and the rehabilitation projects have been assessed applying AHP. The indicators most valued by panelists have been CUH and RIN with 28% and 25% respectively. In third position, IWS indicator has obtained a weight of 18%. The four remaining indicators represent a 29% of the total priority as shown in Table 2. The VIKOR method has been implemented to guarantee a consensus solution. To this end, the weight of decision making strategy in VIKOR has been set to 0.5. The VIKOR analysis has highlighted the PS cross section as the best option.

The PS cross section has achieved an acceptable advantage and stability over the MS cross section, valued as second, as shown in Table 5 and Table 6. Therefore, developing of the PS project solution would facilitate the optimal integration of the river in the landscape of Cuenca. It can be seen in Fig. 3 a clear difference between the PS, GS and MS and the other three cross sections. These differences are shown especially in the project integration with historic buildings and landscape corresponding to the indicators CUH and NAH. Moreover, there is an improvement of the environmental aspects corresponding to the indicators RIN, IWS and WAF in these rehabilitation projects. In addition, the PS rehabilitation project increases the riparian vegetation and water movement that helps in decreasing temperatures and sounds in the historic urban environment according to the indicator IWS.

5. Conclusions

The multitude of different goals and threats prioritized by each stakeholder hinders to find consensus in river rehabilitation projects. This situation begs for the adoption of systematic and comprehensive decision making techniques by panelists. Moreover, structuring the different viewpoints should benefit authorities and policy-makers when communicating such a decision. The use of this decision support system in the Huecar river rehabilitation project has enhanced transparency and consensus as outlined previously. And the stable compromise solution achieved with the proposed hybrid decision support system takes into account different aspects such as social, cultural, landscape, environmental and economic indicators. The proposed hybrid model has proven to be a systematic and comprehensive method in decision making for selecting the optimal project for the rehabilitation of a river in a landscape with great cultural heritage. The Delphi procedure improves the efficiency of the dynamic process of the panelists. Within this context, hierarchical analysis has facilitated explicit discussion of goals and threats. The hierarchy structure of the rehabilitation projects and the indicators has been constructed by the panelists' anonymous open-ended questionnaires in order to achieve consensus. The rehabilitation projects are assessed through a hierarchical structure of several levels using the AHP method. The measurement of the intangibles has been the key point for selecting this technique. In addition, the AHP has analyzed the consistency of the panelists' judgements. The VIKOR technique has been particularly helpful in ensuring consensus in the decision making process by the multi-stakeholder panel. Finally, this hybrid model has improved transparency in the river rehabilitation assessment. As shown, the proposed Delphi-AHP-VIKOR hybrid method has been reliable to reach a consensus rehabilitation project for the Huecar river through a structured decision support system using a multidisciplinary panel of experts.

References

Akiner, I., Akiner, E., 2010. Sustainable urban development: a case study on Goksu Delta. Conference on Water Observation and Information System for Decision Support Ohrid, Balwois.

Becker, N., Helgeson, J., Katz, D., 2014. Once there was a river: a benefit–cost analysis of rehabilitation of the Jordan River. Reg. Envir. Chang 14 (4), 1303-1314, http://dx.doi.org/10.1007/s10113-013-0578-4.

Brida, J.G., Meleddu, M., Pulina, M., 2013. Factors influencing length of stay of cultural tourists. Tour. Econ. 19 (6), 1273-1292, http://dx.doi.org/10.5367/te.2013.0248.

Canto-Perello, J., Curiel-Esparza, J., 2006. An analysis of utility tunnel viability in urban areas. Civ. Eng. Environ. Syst. 23 (1), 11-19, http://dx.doi.org/10.1080/10286600600562129.

Canto-Perello, J., Curiel-Esparza, J., Calvo, V., 2009. Analysing utility tunnels and highway networks coordination dilemma. Tunn. Undergr. Space Technol. 24(2), 185-189, http://dx.doi.org/10.1016/j.tust.2008.07.004.

Canto-Perello, J., Curiel-Esparza, J., Calvo, V., 2016. Strategic decision support system for utility tunnel's planning applying A'WOT method. Tunn. Undergr. Space Technol. 55, 146-152, http://dx.doi.org/ 10.1016/j.tust.2015.12.009.

Carles, J.L., Lopez-Barrio, I., Lucio, J.V., 1999. Sound influence on landscape values. Landsc. Urban Plan. 43 (4), 191-200, http://dx.doi.org/10.1016/S0169-2046(98)00112-1.

Curiel-Esparza, J., Cuenca-Ruiz, M.A., Martin-Utrillas, M., Canto-Perello, J., 2014. Selecting a sustainable disinfection technique for wastewater reuse projects. Water 6 (9), 2732-2747, http://dx.doi.org/10.3390/w6092732.

Curiel-Esparza, J., Gonzalez-Utrillas, N., Canto-Perello J., Martin-Utrillas, M., 2015. Integrating climate change criteria in reforestation projects using a hybrid decision-support system. Environ. Res. Lett. 10 (9), 094022, http://dx.doi.org/10.1088/1748-9326/10/9/094022.

Curiel-Esparza, J., Mazario-Diez, J.L., Canto-Perello, J., Martin-Utrillas, M., 2016. Prioritization by consensus of enhancements for sustainable mobility in urban areas Environ. Sci. Policy 55 (1), 248-257, http://dx.doi.org/10.1016/j.envsci.2015.10.015.

European Union, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 Oct 2000 on the management of the water in the EU. Official Journal of the European Union, 182, 0001-0019.

Fallahpour, A.R., Moghassem, A.R., 2012. Evaluating applicability of VIKOR method of multicriteria decision making for parameters selection problem in rotor spinning. Fiber. Polym. 13 (6), 802- 808, http://dx.doi.org/10.1007/s12221-012-0802-8.

Galbrun, L., Ali, T.T., 2013. Acoustical and perceptual assessment of water sounds and their use over road traffic noise. J. Acoust. Soc. Am. 133 (1), 227-237, http://dx.doi.org/10.1121/1.4770242.

Gracht, H.A., 2012. Consensus measurement in Delphi studies, review and implications for future quality assurance. Technol. Forecast. Soc. Chang. 79 (8), 1525-1536, http://dx.doi.org/10.1016/j.techfore.2012.04.013.

Hale, J.D., Hunt, D.V.L., Pugh, T.A.M., MacKenzie, A.R., Sadler, J.P., Rogers, C.D.F., 2014 Future Proofing the Benefits of Urban Tree Planting. Urban Trees Research Conference, 209-213. University of Birmingham, Edgbaston, UK.

Hathway, E.A., Sharples, S., 2012. The interaction of rivers and urban form in mitigating the Urban Heat Island effect: a UK case study. Build. Environ. 58, 14-22, http://dx.doi.org/10.1016/j.buildenv.2012.06.013.

Hu, H.A., Chen, S.H. Hsu, C.W., Wang, C., Wu, C.L., 2012. Development of sustainability evaluation model for implementing product service systems. Int. J. Environ. Sci. Technol. 9, 343-354, http://dx.doi.org/10.1007/s13762-012-0037-7.

Jeon, J.Y., Lee, P.J., You, J., Kang, J., 2012. Acoustical characteristics of water sounds for soundscape enhancement in urban open spaces. J. Acoust. Soc. Am. 131 (3), 2101-2109, http://dx.doi.org/10.1121/1.3681938.

Jiang, Y., Shi, T., Gu, X., 2016. Healthy urban streams: The ecological continuity study of the Suzhou creek corridor in Shanghai. Cities 59, 80-94. http://dx.doi.org/10.1016/j.cities.2016.06.002.

Kamaruzzaman, S.N., Lou, E.C.W., Zainon, N., Zaid, N.S.M., Wong, P.F., 2016. Environmental assessment schemes for non-domestic building refurbishment in the Malaysian context. Ecol. Indic. 69, 548-558, http://dx.doi.org/10.1016/j.ecolind.2016.04.031.

Lee, H., Hsieh, H.P., 2016. Indicators of sustainable tourism: A case study from a Taiwan's wetland. Ecol. Indic. 67, 779-787, http://dx.doi.org/10.1016/j.ecolind.2016.03.023.

Li, F., Wang, R., Hu, D., Ye, Y., Yang, W., Liu, H., 2014. Measurement methods and applications for beneficial and detrimental effects of ecological services. Ecol. Indic. 47, 102-111, http://dx.doi.org/10.1016/j.ecolind.2014.06.032.

Liaghat, M., Shahabi, H., Deilami, B.R., Ardabili, F.S., Seyedi, S.N., Badri, H., 2013. A multi-criteria evaluation using the analytic hierarchy process technique to analyze coastal tourism sites. APCBEE Procedia 5, 479-485. http://dx.doi.org/10.1016/j.apcbee.2013.05.081

Liou, J.J.H., Tsai, C., Lin, R., Tzeng, G., 2011. A modified VIKOR multiple criteria decision method for improving domestic airlines service quality. J. Air Transp. Manag. 17 (2), 57- 61, http://dx.doi.org/10.1016/j.jairtraman.2010.03.004.

Luderitz, V., Speierl, T., Langheinrich, U., Volkl, W., Gersberg, R.M., 2011. Restoration of the Upper Main and Rodach rivers - The success and its measurement. Ecol. Eng. 37(12), 2044-2055, http://dx.doi.org/10.1016/j.ecoleng.2011.07.010.

Mardani, A., Zavadskas, E.K., Govindan, K., Senin A.A., Jusoh, A., 2016. VIKOR Technique: A Systematic Review of the State of the Art Literature on Methodologies and Applications. Sustainability 8(1), 37, http://dx.doi.org/10.3390/su8010037.

Martin-Utrillas, M., Reyes-Medina, M., Curiel-Esparza, J., Canto-Perello, J., 2015a. Hybrid method for selection of the optimal process of leachate treatment in waste treatment and valorization plants or landfills. Clean Technol. Environ. Policy 17 (4), 873-885, http://dx.doi.org/10.1007/s10098-014-0834-4.

Martin-Utrillas, M., Juan-Garcia, F., Canto-Perello, J., Curiel-Esparza, J., 2015b. Optimal infrastructure selection to boost regional sustainable economy. Int. J. Sustain. Dev. World Ecol. 22 (1), 30-38, http://dx.doi.org/10.1080/13504509.2014.954023.

Matthews, J.C., Allouche, E.N., Sterling, R.L., 2015. Social cost impact assessment of pipeline infrastructure projects. Environ. Impact Assess. Rev. 50, 196-202, http://dx.doi.org/10.1016/j.eiar.2014.10.001.

Mejia, A.I., Reed, S.M., 2011. Evaluating the effects of parameterized cross section shapes and simplified routing with a coupled distributed hydrologic and hydraulic model. J. Hydrol. 409 (1-2), 512-524, http://dx.doi.org/10.1016/j.jhydrol.2011.08.050.

Mitsch, W.J., Jorgensen, S.E., 2004. Ecological Engineering and Ecosystem Restoration. John Wiley & Sons, New Jersey. 99-125.

Mousavi, S.H., Danehkar, A., Shokri, M.R., Poorbagher, H., Azhdari, D., 2015. Site selection for artificial reefs using a new combine Multi-Criteria Decision-Making (MCDM) tools for coral reefs in the Kish Island - Persian Gulf. Ocean Coastal Manage. 111, 92-102, http://dx.doi.org/10.1016/j.ocecoaman.2015.03.004.

Nagy, K., 2012. Heritage Tourism, thematic routes and possibilities for innovation. Theory Methodology Practice 8 (1), 46-53.

Norouzian-Maleki, S., Bell, S., Hosseini, S.B., Faizi, M., 2015. Developing and testing a framework for the assessment of neighbourhood liveability in two contrasting countries: Iran and Estonia. Ecol. Indic. 48, 263-271, http://dx.doi.org/10.1016/j.ecolind.2014.07.033.

Opricovic, S., Tzeng, G., 2007. Extended VIKOR method in comparison with outranking methods. Eur. J. Oper. Res. 178 (2), 514-529, http://dx.doi.org/10.1016/j.ejor.2006.01.020.

Opricovic, S., 2009. A Compromise Solution in Water Resources Planning. Water Resour. Manag. 23 (8), 1549-1561, http://dx.doi.org/10.1007/s11269-008-9340-y.

Opricovic, S., 2011. Fuzzy VIKOR with an application to water resources planning. Expert Syst. Appl. 38(10), 12983-12990, http://dx.doi.org/10.1016/j.eswa.2011.04.097.

Radsten-Ekman, M., Axelsson, O., Nilsson, M.E., 2013. Effects of sounds from water on perception of acoustic environments dominated by road-traffic noise. Acta Acust. United Acust. 99 (2), 218-225, http://dx.doi.org/10.3813/AAA.918605.

Roubelat, F., 2011. The Delphi method as a ritual: inquiring the Delphi Oracle. Technol. Forecast. Soc. Chang. 78 (9), 1491-1499, http://dx.doi.org/10.1016/j.techfore.2011.04.012.

Saaty, T.L., 2012a. Global awareness, future city design and decision making. J. Syst. Sci. Syst. Eng. 21 (3), 337-355, http://dx.doi.org/10.1007/s11518-012-5196-z.

Saaty, T.L., 2012b. Decision making for leaders. The analytic hierarchy process for decisions in a complex world. Pittsburgh: RWS Publications.

Shang, D., Yin, G., Li, X., Li, Y., Jiang, C., Kang, X., Liu, C., Zhang, C., 2015. Analysis for Green Mine (phosphate) performance of China: An evaluation index system. Resour. Policy 46, 71-84, http://dx.doi.org/10.1016/j.resourpol.2015.08.005.

Song, G., Li, Z., Yang, Y., Semakula, H.M., Zhang, S., 2015. Assessment of ecological vulnerability and decision-making application for prioritizing roadside ecological restoration: A method combining geographic information system, Delphi survey and Monte Carlo simulation. Ecol. Indic. 52, 57-65, http://dx.doi.org/10.1016/j.ecolind.2014.11.032.

Tanago, M.G., Jalon, D.G., Roman, M., 2012. River Restoration in Spain: Theoretical and Practical Approach in the context of the European Water Framework Directive. Environ. Manage. 50 (1), 123-139, http://dx.doi.org/10.1007/s00267-012-9862-1.

Tavakkoli-Moghaddam, R., Mousave, S.M., 2011. An integrated AHP-VIKOR methodology for plan location selection. Reserch note. International Journal of Engineering, Transactions B: Applications 24 (2), 127-137.

Turskis, Z.; Zavadskas, E.K.; Kutut, V., 2013. A model based on ARAS-G and AHP methods for multiple criteria prioritizing of heritage value. Int. J. Inf. Technol. Decis. Mak. 12 (1), 45-73, http://dx.doi.org/10.1142/S021962201350003X.

UNESCO, 1995. The Historic Walled Town of Cuenca. World Heritage List: Declaration Nº781.

UNESCO, 2006. Criteria for Selection for World Heritage List. Retrieved 14 October. http://whc.unesco.org/en/criteria/

UN-Water, 2015. The United Nations World Water Development Report 2015: Water for a Sustainable World. Paris, UNESCO.

Valiani, A., Caleffi, V., 2009. Analytical findings for power law cross-sections: uniform flow depth. Adv. Water Resour. 32 (9), 1404-1412, http://dx.doi.org/10.1016/j.advwatres.2009.06.004.

Wang, T., Xu, S., 2015. Dynamic successive assessment method of water environment carrying capacity and its application. Ecol. Indic. 52, 134-146, http://dx.doi.org/10.1016/j.ecolind.2014.12.002.

Wey, W.M., Hsu, J., 2014. New Urbanism and Smart Growth: Toward achieving a smart National Taipei University District. Habitat Int. 42, 164-174, http://dx.doi.org/http://dx.doi.org/

Zhang, J., Ji, M., Zhang Y., 2015. Tourism sustainability in Tibet - Forward planning using a systems approach. Ecol. Indic. 56, 218-228, http://dx.doi.org/10.1016/j.ecolind.2015.04.006.

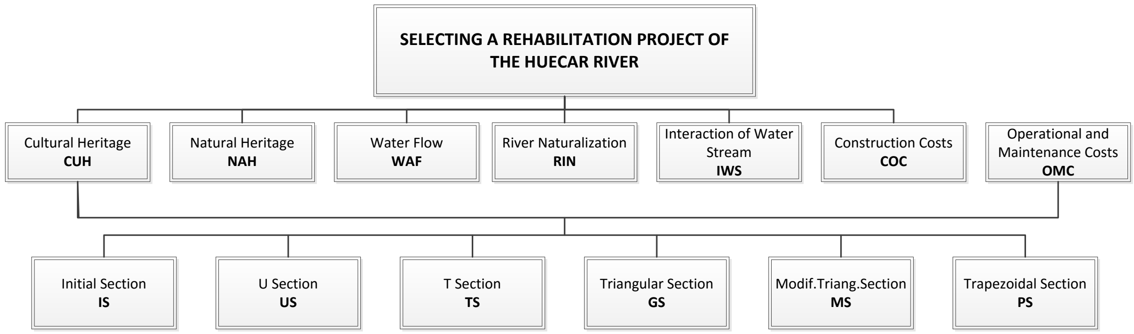

Fig. 1. Hierarchy structure for selecting a rehabilitation project for the Huecar river.

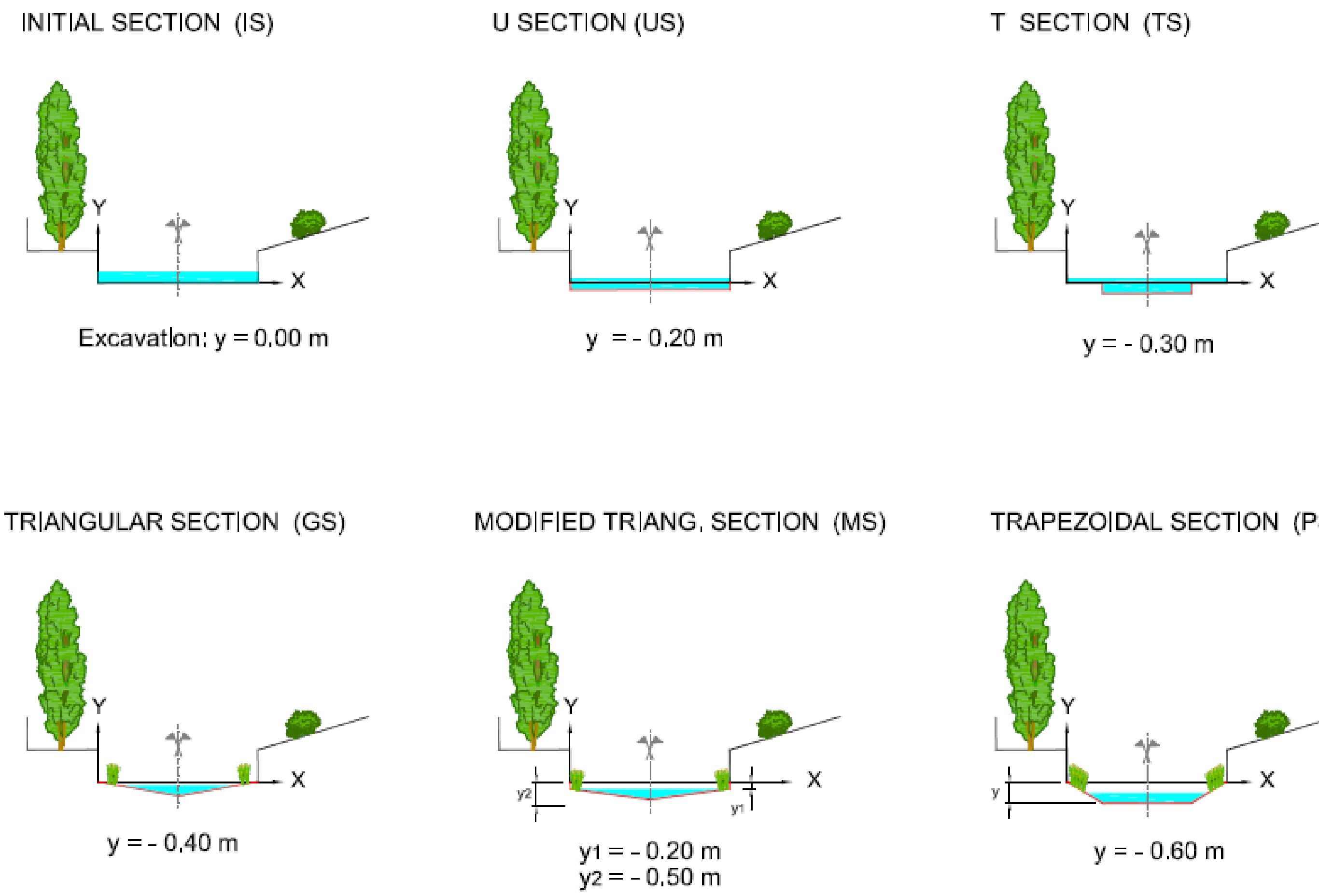

Fig. 2. Proposed cross sections for the urban rehabilitation project.

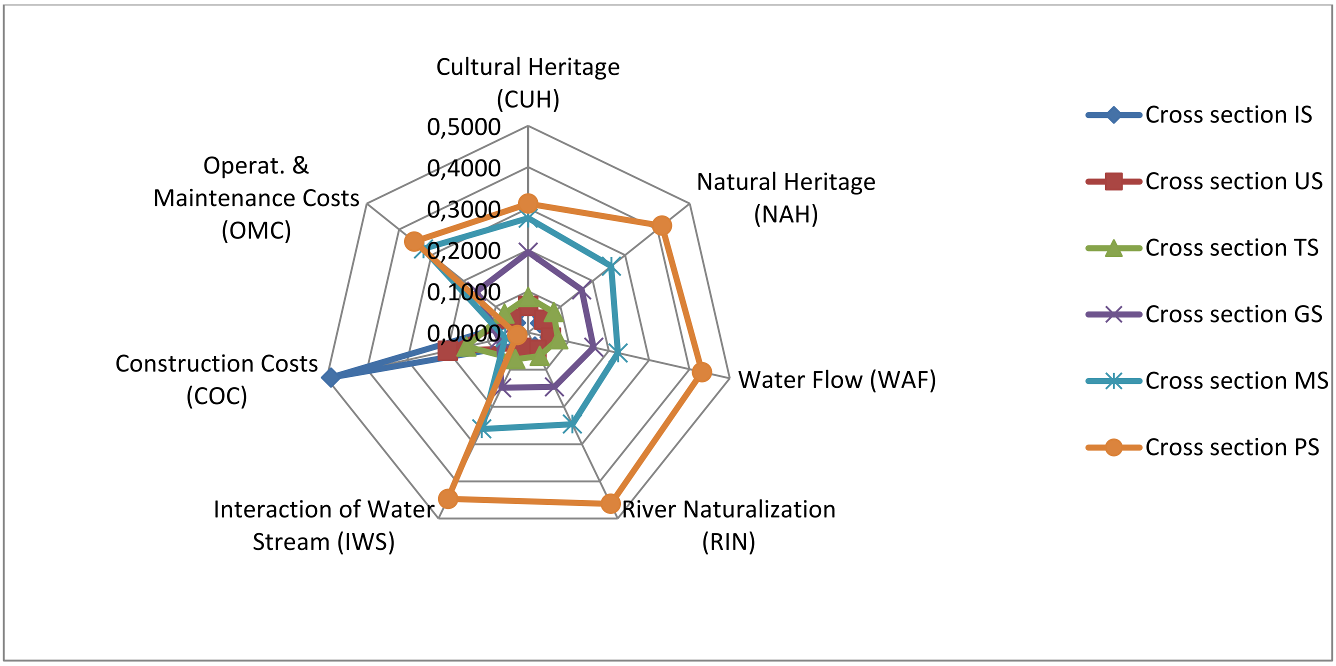

Fig. 3. Priority results for the cross sections according to the indicators.

Table 1
Questionnaire to assess main indicators in the selection of the rehabilitation project.

If this indicator is the most important of two in the row, indicate the degree of importance										If this indicator is the most important of two in the row, indicate the degree of importance
Cultural Heritage (CUH)	9	7	5	3	1	3	5	7	9	Natural Heritage (NAH)
Cultural Heritage (CUH)	9	7	5	3	1	3	5	7	9	Water Flow (WAF)
Cultural Heritage (CUH)	9	7	5	3	1	3	5	7	9	River Naturalization (RIN)
Cultural Heritage (CUH)	9	7	5	3	1	3	5	7	9	Interaction of water (IWS)
Cultural Heritage (CUH)	9	7	5	3	1	3	5	7	9	Construction Costs (COC)
Cultural Heritage (CUH)	9	7	5	3	1	3	5	7	9	Maintenance Costs (OMC)
Natural Heritage (NAH)	9	7	5	3	1	3	5	7	9	Water Flow (WAF)
Natural Heritage (NAH)	9	7	6	3	1	3	5	7	9	River Naturalization (RIN)
Natural Heritage (NAH)	9	7	5	3	1	3	5	7	9	Interaction of water (IWS)
Natural Heritage (NAH)	9	7	5	3	1	3	5	7	9	Construction Costs (COC)
Natural Heritage (NAH)	9	7	5	3	1	3	5	7	9	Maintenance Costs (OMC)
Water Flow (WAF)	9	7	5	3	1	3	5	7	9	River Naturalization (RIN)
Water Flow (WAF)	9	7	5	3	1	3	5	7	9	Interaction of water (IWS)
Water Flow (WAF)	9	7	5	3	1	3	5	7	9	Construction Costs (COC)
Water Flow (WAF)	9	7	5	3	1	3	5	7	9	Maintenance Costs (OMC)
River Naturalization (RIN)	9	7	5	3	1	3	5	7	9	Interaction of water (IWS)
River Naturalization (RIN)	9	7	5	3	1	3	5	7	9	Construction Costs (COC)
River Naturalization (RIN)	9	7	5	3	1	3	5	7	9	Maintenance Costs (OMC)
Interaction of Water (IWS)	9	7	5	3	1	3	5	7	9	Construction Costs (COC)
Interaction of Water (IWS)	9	7	5	3	1	3	5	7	9	Maintenance Costs (OMC)
Construction Costs (COC)	9	7	5	3	1	3	5	7	9	Maintenance Costs (OMC)

Tabla 2
Priority vector and consistency analysis of the pairwise comparison matrix for the indicators in the selection of a river cross section.

	CUH	NAH	WAF	RIN	IWS	COC	OMC	Priority vector
CUH	1.0000	1.8089	6.0617	1.1161	1.3797	7.7403	5.5311	0.2800
NAH	0.5528	1.0000	1.7056	0.6834	0.8513	4.7452	2.2708	0.1405
WAF	0.1650	0.5863	1.0000	0.1812	0.3217	2.8071	0.8027	0.0594
RIN	0.8960	1.4633	5.5198	1.0000	1.1746	7.0569	4.9939	0.2478
IWS	0.7248	1.1746	3.1090	0.8513	1.0000	5.6415	2.8071	0.1805
COC	0.1292	0.2107	0.3562	0.1417	0.1773	1.0000	0.3333	0.0287
OMC	0.1808	0.4404	1.2457	0.2002	0.3562	3.0000	1.0000	0.0632

$\lambda_{max} = 7.1104$, CI = 0.0184 , CR = 0.0136 < 0.1 OK

Tabla 3

Priority vector and consistency analysis of the pairwise comparison matrix for the set of river cross sections with respect to each indicator.

indicator CUH	**IS**	**US**	**TS**	**GS**	**MS**	**PS**	**Priority vector**
IS	1.0000	0.8027	0.8960	0.2717	0.2717	0.2717	0.0672
US	1.2457	1.0000	0.5774	0.2882	0.2331	0.2331	0.0643
TS	1.1161	1.7321	1.0000	0.4404	0.2717	0.2800	0.0856
GS	3.6801	3.4700	2.2708	1.0000	0.5774	0.5173	0.1943
MS	3.6801	4.2896	3.6801	1.7321	1.0000	0.7333	0.2767
PS	3.6801	4.2896	3.5714	1.9332	1.3636	1.0000	0.3118
				λ_{max} =6.0739, CI=0.0146, CR=0.0130 < 0.10 OK			
indicator NAH	**IS**	**US**	**TS**	**GS**	**MS**	**PS**	**Priority vector**
IS	1.0000	0.4404	0.3385	0.2180	0.1677	0.1542	0.0360
US	2.2708	1.0000	0.3720	0.2331	0.1779	0.1542	0.0488
TS	2.9542	2.6879	1.0000	0.3333	0.2105	0.1720	0.0787
GS	4.5882	4.2896	3.0000	1.0000	0.4635	0.3562	0.1652
MS	5.9618	5.6215	4.7510	2.1577	1.0000	0.3535	0.2572
PS	6.4836	6.4836	5.8138	2.8071	2.8288	1.0000	0.4141
				λ_{max} = 6.3101, CI = 0.0584, CR = 0.0521 < 0.10 OK			
indicator WAF	**IS**	**US**	**TS**	**GS**	**MS**	**PS**	**Priority vector**
IS	1.0000	1.0000	0.5774	0.3010	0.2215	0.1808	0.0531
US	1.0000	1.0000	0.7192	0.2860	0.2372	0.1968	0.0561
TS	1.7321	1.3904	1.0000	0.4185	0.2602	0.2071	0.0744
GS	3.3227	3.4968	2.3898	1.0000	0.5774	0.3749	0.1623
MS	4.5144	4.2154	3.8433	1.7321	1.0000	0.2582	0.2229
PS	5.5311	5.0817	4.8287	2.6673	3.8730	1.0000	0.4312
				λ_{max} = 6.1808, CI = 0.0349, CR = 0.0312 < 0.10 OK			
indicator RIN	**IS**	**US**	**TS**	**GS**	**MS**	**PS**	**Priority vector**
IS	1.0000	0.6444	0.5213	0.2180	0.1690	0.1336	0.0377
US	1.5519	1.0000	0.5173	0.2453	0.1903	0.1503	0.0463
TS	1.9184	1.9332	1.0000	0.3167	0.2142	0.1541	0.0633
GS	4.5882	4.0760	3.1572	1.0000	0.3720	0.2453	0.1460
MS	5.9161	5.2556	4.6689	2.6879	1.0000	0.3010	0.2464
PS	7.4842	6.6541	6.4889	4.0760	3.3227	1.0000	0.4603
				λ_{max} = 6.2467, CI = 0.0470, CR = 0.0420 < 0.10 OK			
indicator IWS	**IS**	**US**	**TS**	**GS**	**MS**	**PS**	**Priority vector**
IS	1.0000	0.4915	0.3590	0.1936	0.1528	0.1260	0.0318
US	2.0345	1.0000	0.3167	0.2000	0.1808	0.1325	0.0415
TS	2.7855	3.1572	1.0000	0.3010	0.2035	0.1541	0.0717
GS	5.1648	5.0000	3.3227	1.0000	0.3333	0.2331	0.1488
MS	6.5444	5.5311	4.9136	3.0000	1.0000	0.3516	0.2590
PS	7.9373	7.5482	6.4890	4.2896	2.8439	1.0000	0.4472
				λ_{max} = 6.3795, CI = 0.0705, CR = 0.0630 < 0.10 OK			
indicator COC	**IS**	**US**	**TS**	**GS**	**MS**	**PS**	**Priority vector**
IS	1.0000	4.2154	4.7452	6.4890	6,4890	8.3464	0.4900
US	0.2372	1.0000	1.8228	3.6165	4.2154	6.4890	0.1999
TS	0.2107	0.5486	1.0000	3.3227	3.6801	5.9161	0.1534
GS	0.1541	0.2765	0.3010	1.0000	1.7321	4.0760	0.0721
MS	0.1541	0.2372	0.2717	0.5774	1.0000	3.6801	0.0571
PS	0.1198	0.1541	0.1690	0.2453	0.2717	1.0000	0.0276
				λ_{max} = 6.3863, CI = 0.0717, CR = 0.0640 < 0.10 OK			
indicator OMC	**IS**	**US**	**TS**	**GS**	**MS**	**PS**	**Priority vector**
IS	1.0000	0.5173	0,3333	0.2105	0.1748	0.1528	0.0375
US	1.9332	1.0000	0.5774	0.2453	0.1870	0.1690	0.0525
TS	3.0000	1.7321	1.0000	0.3167	0.1934	0.1870	0.0733
GS	4.7510	4.0760	3.1572	1.0000	0.3167	0.3010	0.1595
MS	5.7203	5.3481	5.1711	3.1572	1.0000	0.8960	0.3245
PS	6.5444	5.9161	5.3481	3.3227	1.1161	1.0000	0.3526
				λ_{max} = 6.2203, CI = 0.0422, CR = 0.0377 < 0.10 OK			

Table 4

Matrix with the priority vectors of the different cross sections with respect to each indic

	CUH	NAH	WAF	RIN	IWS	COC
IS	0.0672	0.0360	0.0531	0.0377	0.0318	0.4900
US	0.0643	0.0488	0.0561	0.0463	0.0415	0.1999
TS	0.0856	0.0787	0.0744	0.0633	0.0717	0.1534
GS	0.1943	0.1652	0.1623	0.1460	0.1488	0.0721
MS	0.2767	0.2572	0.2229	0.2464	0.2590	0.0571
PS	0.3118	0.4141	0.4312	0.4603	0.4472	0.0276

Table 5
S, R and Q values for the cross sections selection.

indicators	fi*	fi^	Wi	IS	US	TS	GS	MS	PS	
CUH	0.3118	0.0643	0.2800	0.0672	0.0643	0.1422	0.1665	0.2767	0.3118	
NAH	0.6175	0.0360	0.1405	0.0360	0.0488	0.1320	0.1600	0.2572	0.6175	
WAF	0.5943	0.0531	0.0594	0.0531	0.0561	0.0895	0.1886	0.2229	0.5943	
RIN	0.5943	0.0377	0.2478	0.0377	0.0561	0.0895	0.1886	0.2464	0.5943	
IWS	0.6348	0.0317	0.1805	0.0318	0.0414	0.0946	0.1858	0.2590	0.6349	S*= 0.0331
COC	0.4899	0.0435	0.0287	0.4900	0.1998	0.1167	0.0972	0.0571	0.0435	R* = 0.0287
OMC	0.3245	0.0375	0.0632	0.0375	0.0525	0.3043	0.3043	0.3245	0.3044	
			Sj	0.9721	0.9680	0.7792	0.7792	0.4627	0.0331	S^= 0.9721
			Rj	0.2800	0.2767	0.2247	0.1805	0.1549	0.0287	R^= 0.2800
			Qj	0.9890	0.9913	0.7873	0.6995	0.4798	0.0000	

Table 6

Ranking of cross sections according to R, S, Q.

Position	1	2	3	4	5
According to S	PS	MS	GS	TS	IS
According to R	PS	MS	GS	TS	IS
According to Q	PS	MS	GS	TS	IS