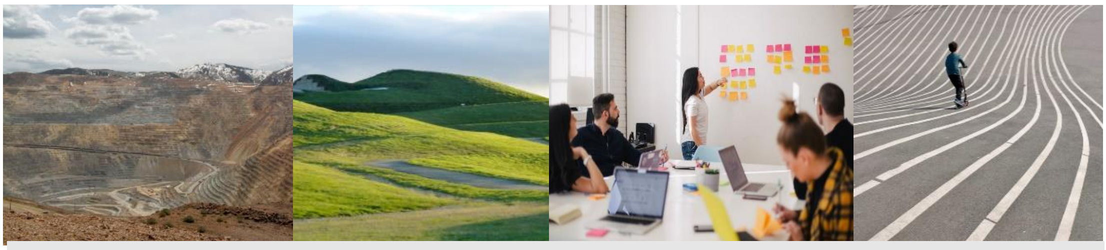
ReviRis
Revitalising Post-Mining Regions



D3.3 MCDM model and environmental, social, cultural, and economic indicators for multi-criteria evaluation of transitional sites and post-mining areas

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D3.3 MCDM model and environmental, social, cultural, and economic indicators for multi-criteria evaluation of transitional sites and post-mining areas

Summary

In this report are presented simple analysis of the most used Multi-Criteria Decision Methods (MCDM), the concept of Multi-Criteria Spatial Decision Support Systems (MC-SDSS), and the main topic to address in a Post-Mining Land Use context.

With these concepts in mind and together with the contributions of ReviRIS partners, this report intends to be a preliminary design for the following steps of ReviRIS tool's development.

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List of abbreviations

DM	Decision maker
GIS	Geographical Information System
IDM	Initial Decision Matrix
MCDM	Multi-criteria Decision Method
MC-SDSS	Multi-criteria Spatial Decision Support System
PMLU	Post-Mining Land Use
TEP	Transitional Evolutionary Profiles

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1 INTRODUCTION

The ReviRIS project aims at developing a Multi-Criteria Spatial Decision Support System (MC-SDSS) to help in the decision-making regarding the choice for a revitalisation strategy.

The WP3 of ReviRIS EIT Raw Materials' project aims at the development of a Multi-Criteria Decision Analysis (MCDA) to be implemented in a Spatial Decision Support System (SDSS) to help in decision-making for the choice of a revitalisation strategy, of transitional and post-mining areas.

To achieve that goal, WP3 is divided into three tasks, namely:

- Task 3.1 Establishment of the social, environmental, cultural, and economic indicators specific to the transitional and post-mining condition,
- Task 3.2 Establishment of a site-specific matrix for a definition of transitional evolutionary profiles,
- Task 3.3 Development of preliminary MCDA toolkit.

1.1 Report's framing

This report regards task 3.3, which main objective is to develop a preliminary MCDA toolkit, to which AGH UST, NTUA and TT partners have contributed.

To develop this preliminary MCDA toolkit, a distinction between several possible multi-criteria decision methods is made to help in the selection of the most suited MCDA technique for further application. The preliminary toolkit's application should consider the following:

1. transitional landscape profiles (D3.2),
2. type of analytical and spatial data to be integrated (according with D3.1),
3. possibilities of ranking and weighing to allow the inclusion of uncertainty and risk in the decision process.

The toolkit will be optimized and improved in WP5 after its experimental application to WP4 case studies.

1.2 Background

MCDA is a sub-field of Operations Research and Management Science (Munier et al., 2019) that intends to develop and apply methods to help a decision maker in the reasoning to decide for a solution, providing a way to demonstrate to others the decision process.

In the book of Munier et al. (2019) a brief history of the MCA development is made and although decision making has always been part our lives, the emerge of it as a sub-field started in the World War II, with the Russian Government commissioning to Leonid Kantorovich the determination of the optimal mix of resources and utilities that should be developed to maximise the war effort. Since then, MCDA has evolved under two main streams of influence, namely the utility theory and the multiple objective mathematical programming (Munier et al., 2019).

Nowadays there is a plethora of MCDA techniques that, before implemented need to be properly address with regards to the problem under analysis, because as referred in Munier et al. (2019) "*for a same problem, MCDM methods deliver different results, an anomaly that is known as the 'decision-making paradox*'".

One of the most used method is Analytical Hierarchy Process (AHP) developed by Thomas Saaty in late 1970s, early 1980s. This method is simple of reasoning, application, and ease of use for the decision-maker. The evolving of MCDA methods has led to the combination of AHP with other techniques, for instance Fuzzy AHP, as well as the development of new MCDA techniques, such as TOPSIS, VIKOR, PROMETHEE, ELECTRE, among others.

It is widely used a combination of methods, for instance, AHP to criteria weights, and TOPSIS for alternative ranking, but these hybrid solutions may not be desired due to the nature of the decision maker (DM) subjectivity introduction.

In this report, the most used MCDM methods and MC-SDSS main concept will be described, and the Post-Mining Land Use (PMLU) context will also be briefly described. With these considerations, the other WP3 deliverables, and ReviRIS partners' vision to this tool, this report will present the preliminary ReviRIS tool conceptualisation.

2 MCDA METHODS

In this chapter, will be given a brief description of the main theoretical concepts and premisses for each MCDA method under analysis. At the same time, they will be grouped under full aggregation methods, outranking methods, and goal programming or reference methods, according with the literature.

2.1 Full aggregation methods

Full aggregation methods usually are subjective, compensatory (a low performance in one criterion is compensated by a better performance in another criterion) and the criteria must be independent. They are easily understandable, but the values introduced regard preferences of the DM, instead of real data.

Analytic Hierarchy Process (AHP)

AHP was developed by Tomas L. Saaty in the late 1970s, early 1980s (Munier et al., 2019; Saaty, 1980), and is the most used method. This method is based on the additive concept established by multiple attribute utility theory (MAUT) (Munier et al., 2019), which implies that criteria are independent (Tzeng & Huang, 2011).

This method applies pairwise comparison matrix between criteria to generate their weights, through the calculation of an eigenvector, and then applies the weights to alternatives assessment (Munier et al., 2019). This pairwise comparison matrix is based on DM judgemental preferences from 1 to 9 (Saaty, 1984). This scale corresponds to a ratio scale (Ishizaka & Nemery, 2013) where, if criteria A is more important than B, then it will be assign 7 to A and 1/7 to B.

For the pairwise comparison be used in the process, it needs to be consistent. To analyse the consistency, a series of mathematical calculations are performed and the consistency index (CI) is found. This value is then compared with random indices (RI) to generate the consistency ratio (CR) (Bascetin, 2007). For the pairwise comparisons be considered consistent the CR must be equal or less than 0.10. If this doesn't happen, the judgemental preferences given for the DM need to be revised (Saaty, 1984).

The RI are randomly generated reciprocal matrices, meaning they are a defined value in the literature, and they are linked with the order of the matrix (Bascetin, 2007), which means that the number of criteria or alternatives must be equal or less than the value of RI in the literature. Bascetin (2007) uses a table that has 15 values for RI, although the author of the method uses a RI table with 8 values (Saaty, 1984).

Summarising, the main points of AHP are as follows:

- criteria must be independent,
- criteria weights are based on judgemental preferences of the DM, that need to be consistent ($CR \leq 0.10$),
- the CR must be equal or below 0.10 and, if not, the DM need to revise his preferences,
- there is a limit to the number of criteria and alternatives, due to the RI values,
- the mathematical calculations are not very complex.

Analytic Network Process (ANP)

ANP was also developed by Tomas L. Saaty and is a general form of the AHP, in other words, AHP is a special case of ANP (Saaty, 2004).

The main difference between ANP and AHP is that, the former, can handle with dependent criteria, which in turn can be clustered or not, and is modelled in a super matrix (Ishizaka & Nemery, 2013). This super matrix is where all criteria relations are displayed through the same preference scale of AHP (1 to 9).

Since it is a generalised form of the AHP, the mathematical equations are similar, although for the super matrix there is the need to have higher computational iterations.

The main points of ANP are as follows:

- criteria can be dependent,
- criteria weights are based on judgemental preferences of the DM, that need to be consistent (CR ≤ 0.10),
- the CR must be equal or below 0.10 and, if not, the DM need to revise his preferences,
- there is a limit to the number of criteria and alternatives, due to the RI values,
- the mathematical calculations are slightly more complex than in AHP.

MACBETH

According to Ishizaka & Nemery (2013), this method is also categorised as full aggregation MCDM method, makes use of judgements form the DM, and applies linear programming (LP) in its calculations procedures. This method was created by Bana e Costa & Vansnick (1994) and it stands for “Measuring Attractiveness by a Categorical Based Evaluation Technique”.

This method also uses pairwise comparison, but its scale is different, as well as the mathematical procedure. While for AHP the scale is based on a ratio, in MACBETH, the scale corresponds to difference between criteria under comparison, which scale is from 1 to 7 (Ishizaka & Nemery, 2013).

As with the AHP and ANP, if the pairwise comparison matrix is not consistent, the DM needs to revise their judgements. In MACBETH is required a high consistency and, for that, whenever a judgement is introduced the consistency need to be checked. In this method the consistency is checked through an assessment of the semantic judgements and the incoherent consistency (Ishizaka & Nemery, 2013).

For this method be applicable, the DM should know very well the problem and this cannot be inconsistent, as for instance, a football tournament where the highest classified team can lose against the lowest classified team (Ishizaka & Nemery, 2013).

Summarising, the main points of the method is as follows:

- similarity to AHP and ANP in the application (judgements of the DM),
- measures the attractiveness of a criteria through its difference in its value (difference scale),
- requires high consistency check that relates to two aspects, semantic inconsistence and incoherent inconsistency,

- uses LP in its mathematical procedures.
- Criteria must be independent
- Compensatory method

2.2 Outranking methods

These methods present the alternatives not in the form of scores, as the full aggregation methods, but rather, they rank the alternatives according with indexes, and through pairwise comparison of the alternatives (Ishizaka & Nemery, 2013). The indexes are different in number and type between outranking methods. Knowing what influence the ranking requires a profound knowledge of the method by the partitioner.

The outranking methods demand more mathematical calculations and relations, which could be difficult for stakeholders properly understand.

PROMETHEE

The name of this method stands for "Preference Ranking Organization Method for Enrichment Evaluation" and it was originated in Europe, by J. P. Brans (Munier et al., 2019).

To model de decision-making with this method there is the need to find threshold values and other functions, separately from criteria weights. To find these values, the DM should apply his knowledge and expertise, but also be based on standards and statistics.

The main reasoning behind PROMETHEE procedure is if between a pair of alternatives, *A* and *B*, all criteria in *A* are better or equal than the criteria in *B*, with at least one criteria in *A* being strictly better than one in *B*, than, it is said that *A* outrank *B* (Tzeng & Huang, 2011). The outrank is what defined this method as an outranking MCDM method.

To achieve the ranking, there three main phases of the process, as follows (*ibidem*):

1. construction of generalised criteria, where a preference function for each criterion is defined, through the definition of thresholds of preference and indifference,
2. determination of an outrank relation on the alternatives, where a preference index is defined to obtain the outranking relation,
3. evaluation of this relation to give an answer.

PROMETHEE has four versions, all of them differ in some mathematical aspect, or have some features added. Following, there are brief descriptions of each PROMETHEE version, based on the book of Tzeng & Huang (2011):

- **PROMETHEE I**: partial pre-order of the alternatives, where all relations are considered, even the ones that indicate incompatibility between alternatives.
- **PROMETHEE II**: complete pre-order of the alternatives, induced by a net flow.
- **PROMETHEE III**: complete pre-order of a finite set of feasible solutions, applying intervals to each alternative, and using the transitivity nature of alternatives.
- **PROMETHEE IV**: complete pre-order of a continuous set of feasible solutions, induced by a net flow a.

In PROMETHEE I all relations are considered, and the results are given considering outrank, indifference and incompatibility, which may seem hard of analysing. However, it gives more realistic information. In PROMETHEE II the results are easier to understand for the DM, but they miss the loss of information given in a more realistic way.

Regarding PROMETHEE III, the main difference is the application of intervals and transitivity nature, that allow us to distinguish incomparability from indifference. As for PROMETHEE IV, it corresponds to an extension of PROMETHEE II to a continuous set of alternatives, as for instance compositions of alloys, investments, dimensions of products, and so on.

ELECTRE

The name of this method stands for *ELimination Et Choix Traduisant la REalité* [FR - original], developed by Bernard Roy in 1968, and it was created based on the concept of outranking features (Tzeng & Huang, 2011).

ELECTRE method avoids compensation between criteria and normalisation process, which allow for a more realistic approach. On the other hand, the method demands for more complex algorithm and the introduction of many technical parameters (Ishizaka & Nemery, 2013).

The introduction of the technical parameters led to the development of several versions of the method. These features are based on the nature of the problem statement , the degree of significance of the criteria, and the preferential information (Tzeng & Huang, 2011).

Based on Tzeng & Huang (2011) and Ishizaka & Nemery (2013), the main parameters that ELECTRE methods use are as follows

- Indifference threshold indicates the largest difference between the performance's values, on one criterion, such that those alternatives remain indifferent for the DM. This means that a value higher than this threshold indicates a possible preference on one of the alternatives.
- Preference threshold indicates the largest difference between the performance's values, such that one alternative is preferred over another, on the considered criterion. Usually, the preference threshold is higher than the indifference threshold.
- Veto threshold is a parameter that in case an alternative performs badly in one single criterion, it is automatically outranked by the other alternative. Usually, the veto threshold is higher than indifference and preference thresholds.
- Concordance index, which measure how much an alternative is at least as good as another, based on indifference, preference, and veto thresholds. For example, C(a,b) measures how much *a* is at least as good as *b*.
- Discordance index, which measures the degree to which an alternative is strictly preferred to another, based on indifference, preference, and veto thresholds. For example, D(a,b) is the degree to which *b* is strictly preferred to *a*.
- Pseudo-criteria, which were introduced to model the problem when the data are imprecise and uncertain. It is used when DM must decide between alternatives with performances differences smaller than the indifference threshold, or between alternatives with performances differences higher than the preference threshold.

The relation between these features, thresholds, and indexes is complex, but on the other hand allows for the modelling of the uncertainty of the DM without modifying real and objective data.

In the ELECTRE method, the introduction of these features served to complement the original method (ELECTRE I) and so, several methods have been proposed and used for different situations, and with different features. A brief description of the ELECTRE methods, based on the explanations of Ishizaka & Nemery (2013) and Tzeng & Huang (2011), is as follows:

- **ELECTRE I:** it uses concordance and discordance indexes to select a subset of alternatives that contains the best option. An improvement of this method is the introduction of veto threshold (ELECTRE Iv) and the introduction of pseudo-criteria (ELECTRE Is).
- **ELECTRE II:** can be considered as an extension of ELECTRE I in the way that is produces a pre-ordered sub-set of alternatives. ELECTRE II uses binary (or crisp) outranking relations, but don’t make use of pseudo-criteria.
- **ELECTRE III:** also produces a pre-ordered subset of alternatives but using pseudo-criteria and outranking degrees, to introduce DM preferences in fuzzy conditions.
- **ELECTRE IV:** intends to be a simplified version of ELECTRE III, where the main difference is that criteria weights are not needed.
- **ELECTRE-Tri:** this is a sorting method, meaning that is assigns alternatives into ordered categories. For example, it can prioritize projects under the categories of low, medium, high priority. These categories can be defined by limiting profiles or boundaries (ELECTRE-Tri-B), or by central profiles or centroids (ELECTRE-Tri-C).

These ELECTRE methods can be applied to different type of decision problem, as in **Table 2-1**.

***Table 2-1**: Table with the suitability of ELECTRE methods according with the main types of decision problems (adapted from Ishizaka & Nemery (2013))*

Decision Problem	Method
Choice problem	ELECTRE I ELECTRE Iv ELECTRE Is
Ranking problem	ELECTRE II ELECTRE III ELECTRE IV
Sorting problem	ELECTRE-Tri-B ELECTRE-Tri-C

2.3 Goal, aspiration, or reference level approach

These category of methods uses several techniques to measure the distance of criteria or alternatives to an ideal solution. It may use positive and negative ideal solutions (PIS and NIS). These methods to not provide a ranking list of alternatives, but rather return a compromise solution considering the ideal one.

TOPSIS

The full name of this is Technique for Order Preferences by Similarity to an Ideal Solution and it was proposed by Hwang and Yoon in 1981 and, instead for using scores as full aggregation methods, or using rankings as outranking methods, TOPSIS makes use of the concept of compromise solution (Tzeng & Huang, 2011).

The best solution corresponds to one that is closest to a positive ideal solution (PIS) and farthest from the negative ideal solution (NIS). At a final step, it sorts the alternatives based on their similarity to PIS in descending order, determining the first as the best alternative (*idem*).

To determine the closeness to PIS and NIS, the Euclidean distance must be calculated, which uses values given to criteria. In this method the criteria are divided into benefit and cost criteria. For the first, larger is better; for the second, smaller is better, and to the definition of these criteria, the desired and worst (non-desired) values must be given to determine the Euclidean distance to PIS and NIS (*idem*).

VIKOR

The name stands for VIseKriterijumska Optimizacija I Kompromisno Resenje. It is somehow like TOPSIS, giving compromise lists, and the compromise solution, but adds information regarding weight stability intervals, and introduces the multicriteria ranking index. Another aspect of this method is that it works in the presence of conflicting criteria (Tzeng & Huang, 2011).

This method uses linear programming (LP) techniques to compare the measure of closeness to the ideal solution (*ibidem*). This process generates three lists of alternatives, which are the following:

- S, that corresponds to a maximum group utility, which intends to represent a “majority” rule to show an average gap for improvement priority (the closeness),
- R, which is the minimum individual regret of the “opponent”, to show to maximal gap for improvement priority (considering S),
- Q, corresponds to the relation of the difference of S and R ratios.

The Q ranking list is the one that gives the best compromise solution, which is corresponds the alternative with lowest Q value, meaning the lower gap to the ideal solution.

This method is particularly helpful when DM can’t express his preference at the beginning of the process.

3 MULTI-CRITERIA SPATIAL DECISION SUPPORT SYSTEMS

MC-SDSS is a field of research which aims at the combination of MCDM with GIS techniques. Usually, an MC-SDSS is seen as an enhancement of a Spatial Decision Support Systems (SDSS) with the tools and techniques to accommodate the MCDM modelling.

The SDSS, as well as the MC-SDSS, implies the use of a software that should have the components presented in ***Figure 3-1***.

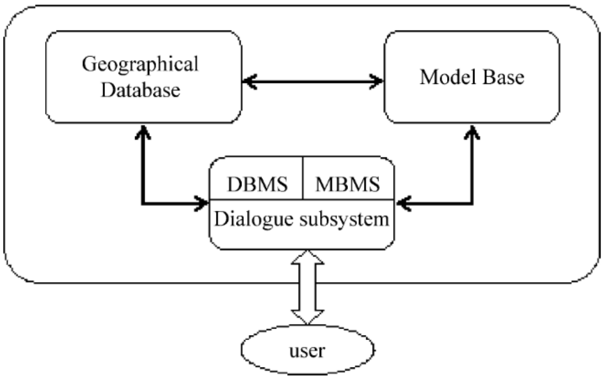

Figure 3-1: *Components of a SDSS* (Chakhar & Mousseau, 2008). *DBMS = DataBase Management Systems. MBMS = Model-Base Management Systems.*

According to Chakhar & Mousseau (2008), to turn a SDSS into a MC-SDSS, the model base must incorporate several MCDM, and the model-based management system (MBMS) must allow multi-criteria spatial modelling.

The physical integration of these components, according with the same author, can be divided into three main modes, as follows:

- **Loose integration (*Figure 3-2*)**: there is the need for two software, one for handling with GIS data and another to handle with MCDM. The communication between the GIS software and MCDM software is made through an intermediate system. The main task of this intermediate system is to reformulate and restructure the data originated in one software, so the data can be used by the other software. In this physical integration, there are two separate databases with each specific interface.

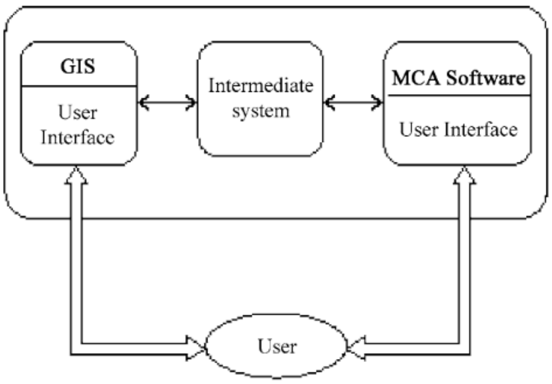

Figure 3-2: *Scheme for Loose physical integration mode* (Chakhar & Mousseau, 2008).

- **Tight integration (*Figure 3-3*)**: In this integration mode, the introduction of one MCDM into the GIS software is directly made, and the interface between the two software is a single one. It still uses two databases, but the intermediate system connects the two parts in a more interactive way.

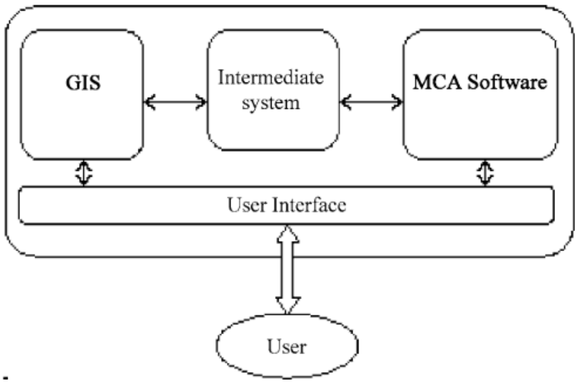

***Figure 3-3:** Scheme for Tight physical integration mode* (Chakhar & Mousseau, 2008).

- **Full integration (*Figure 3-4*):** this mode of physical integration between GIS and MCDM is the most integrated one, with the one single user interface and one single database. The intermediate system is no longer needed and, thus, the communication between MCDM information and GIS data is facilitated. In the figure presented, the main software is GIS, that uses MCDM functions totally developed within GIS interface.

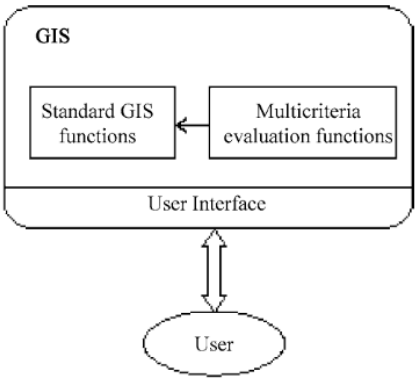

***Figure 3-4:** Scheme for Full physical integration mode* (Chakhar & Mousseau, 2008).

For all these physical integration modes, the direction of interaction between MCDM information and GIS data can occur in the following ways (*idem*):

- **No interaction**, where each software is completely independent.
- **One-directional interaction:** whether with GIS or MCDM as the main software, meaning that, the importing and exporting tasks originates only in one of the software.
- **Bi-directional interaction:** in this type of interaction, the information can be originated either from GIS or MCDM but can also end on one of the them.
- **Dynamic interaction:** this is the most flexible way of interaction and allows for a dynamic flow of information between GIS software and MCDM software.

A complete and detailed list of components that should integrate a MC-SDSS is presented in ***Figure 3-5***. In this figure, it is possible to understand that the Model-Base is the component that supports the GIS and MCDM functions.

Using ArcGIS software as an analogy to the scheme presented in ***Figure 3-5*** and ***Figure 3-1***, the "Model Base" can be considered as the ArcGIS Tool Set, where it is possible to have GIS default tools, as well as new personalised tools (developed through Model Builder or python scripts). The "Geographical Data Base" can be the user's spatial data (shapefile, geodabatase, raster, etc.). The "Dialogue System" may be considered as the ArcGIS user interface, that use the functionalities of the "Spatial Data Base Management System" (DBMS) and "Model Management System" (MBMS).

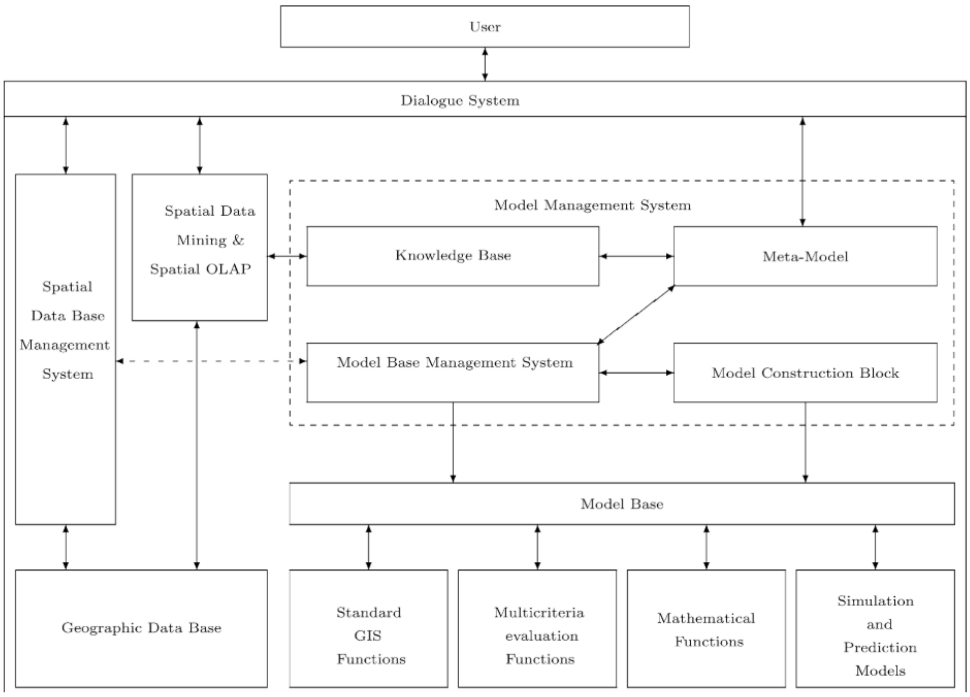

Figure 3-5: *Components of MC-SDSS and the relations and connections between them* (Chakhar & Mousseau, 2008).

4 POST-MINING LAND USE CONTEXT

In decision making, the type of problem can be defined as one of the following (Ishizaka & Nemery, 2013):

1. **Choice problem** is when the DM aims at selecting the best option or, at least, reduce the options to a subset where the best option is included.
2. **Sorting problem** is when the DM needs to categorise several alternatives under predefined ordered categories.
3. **Ranking problem** is when the DM needs to order the alternatives or a subset of them, from best to worst, according to some features.
4. **Description problem** is when the DM needs to understand the options and their consequences. Usually, this understanding is a first step in the decision-making process.
5. **Elimination problem** is considered a branch of the sorting problem.
6. **Design problem** is when the DM needs to identify and create new actions according to his preferences.

With the above types of decision problems, the Post-Mining Land Use (PMLU) context should be integrated to better understand which MCDM can be applied.

In PMLU field of work, there are issues regarding environment problems, social context, economic constraints, regional strategies, and technical engineering issues. Due to the complexity of PMLU, there are some aspect to bear in mind, as follows:

- If the decision is to be taken considering all aspects at once, the MCDM should be able to model complex scenarios,
- If the PMLU context is to be broken down into smaller and simpler parts, the MCDM should be specific to each of those parts,
- The subjectivity of the decision maker (DM) or group of DMs should be analysed, because in some cases their personal preferences can be considered, but in others it should not.

Another important aspect of PMLU context is the type of spatial problem. If it is a location problem, the approach will be different of a planning problem. A very important component of PMLU is environmental issues and land management, after the environmental recovery. This indicates that, PMLU is a complex environmental and land management problem, that will affect the social dimension.

With this definition, the MCDM should be developed for complex environmental and land management problems with influence on local communities. Once the decision will affect local communities, the importance or weights of criteria shouldn’t rely only on DM (or group of DM) preferences, they should be as objective as possible. At the same time, a proper understanding of the type of decision problem must be considered, as it will also guide in the choice for a specific MCDM.

5 PRELIMINARY METHODOLOGY FOR MC-SDSS APPLIED TO POST-MINING PLANNING

This preliminary methodology for MC-SDSS applied to Post-Mining Planning was developed through the research conducted within WP3 and WP5 tasks, and with the valuable contributions of all ReviRIS partners, either through the discussion of the presentations or by answering a questionnaire.

The questionnaire included five questions that will guide the way of designing ReviRIS tool. The questions regarded the following issues

1. Their thought of what should be the tool,
2. Who should be the users,
3. The main purpose of the tool, if to help in selection of the alternative or to help in the development of them
4. The objectives to be included in the tool or the ones that should guide the development of the alternatives or the tool itself,
5. The level of approach of the tool: if it should be at local level (mine site) or at regional level (considering a mining province or region).

Considering the above, which is detailed in the next sub-chapter, and the information on the other deliverables referred in sub-chapter 1.1 - Report's framing, namely criteria and transitional evolutionary profiles, a methodology is proposed in sub-chapter 5.2.

5.1 Summary of the questionnaire

In **Table 5-1** are summarised the main ideas shared through he the answers given to the questionnaire

***Table 5-1**: Main thoughts shared through the questionnaire.*

Thought on the tool	***The user***	***Type of tool***	***Objectives***	***Level of approach***
Participatory process with simple MCDM	Experts (or group)	Selection of alternatives	Case specific	Local
Complex and realistic approach	Team working in Post-Mining projects	Possibility to deepen the analysis in forwarding steps	Focusing on the functions of new land uses	Considering regional and national context
Documentation to present in public consultations	The MCDM partitioner	Virtual or augmented reality simulation (next tool level)	Considering constraints and resources	Possibility to apply at regional level, depending on the similarity and proximity of other sites.
Thought-guidance mechanism	Multiple stakeholders	Pre-establish scenarios	Considering climate chance	
Robust sensitivity analysis	Anyone, with a specific licence		*Depending on preferences of each DM*	
Licenced software				

Given all possible ideas (see table above), the general consensuos is that this should be a tool to select the alternatives and it should be applied at local level (mine site level). it was possible to define four perspectives (***Figure 5-1***), namely the following:

- **Perspective of the end user**: it should be a tool to allow for a participatory process, with simple MCDM, but also allowing for multiple stakeholders make of use of the tool.
- **Perspective of the experts**: it should be a tool to allow a realistic modelling of all the complexities, that are embedded in these situations, by the experts or the team working in the revitalisation process (not directed to all kinds of stakeholders).
- **Perspective of a guidance tool**: it should give a mechanism to guide the user in throughout the process and should allow a robust sensitive analysis, usually the "what if" phase of a MC-SDSS or MCDM.
- **Perspective of a software**: it should be a licenced software, with several levels of licences, with pre-establish scenarios, and with a future perspective for the incorporation of virtual reality or augmented really simulation.

Although many different perspectives were detected, there are two general consensual topics, which are that this should be a tool to help in the selection of the alternatives (selection tool) at local level.

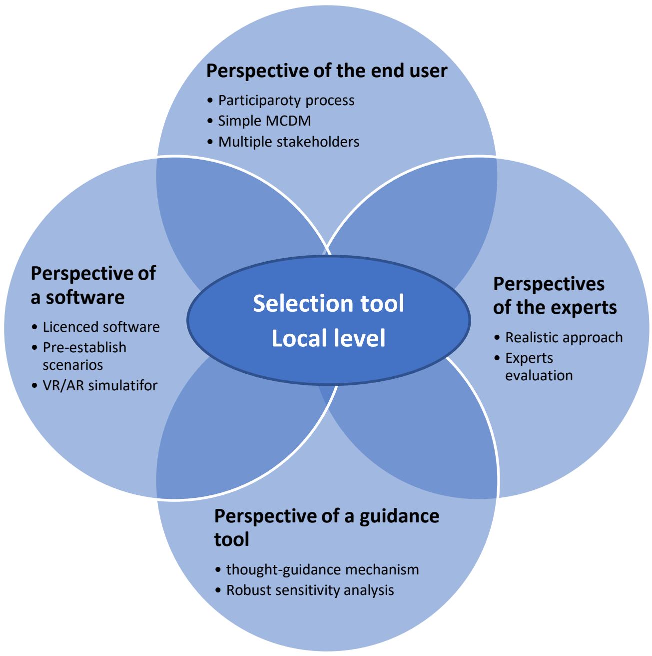

Figure 5-1: *Perspective for ReviRIS tool (own production)(Chakhar & Mousseau, 2008)(Chakhar & Mousseau, 2008)*

Among the four perspectives there are three main inconsistencies, as follows:

- **Between perspective of the experts and simple MCDM:** according with the brief description of the most used MCDM (chapter 2) it is possible to realise that more complex methods, allow for a more realistic approach. The simplest methods allow for the introduction of the DM subjectivity without a proper consideration of the realistic complexity of the problem.
- **Between a selection tool and a thought-guidance tool:** for a selection tool, a starting point can be the Initial Decision Matrix (IDM), where all the alternatives are developed, but there is the need to understand which are the most useful criteria and their performance values to make the evaluation. For the thought-guidance tool, there

should be a mechanism to guide the user to way the tool work or to guide him in the reasoning of the problem to properly develop the alternatives.

- **Software perspective:** this will require more complex and specific skills to develop a proper licenced software, and it might be worth to apply in a forward development of ReviRIS.

With all these contributions, ideas, and concepts, we propose the following methodology for MC-SDSS applied to post-mining planning.

5.2 Proposed METHODOLOGY for MC-SDSS applied to POST-MINING PLANNING

We suggest a 3 phased methodology, that will serve as a thought-guidance mechanism to help the users in the approach of the decision process, considering the complexity of the site, which will depend on the TEP and the type of alternatives developed.

In a more concise way and following the scheme in ***Figure 5-2***, we propose to use the TEP to make a first assessment of the site (1st phase); then, according with the complexity of the site and alternatives designed, a specific MCDM can be applied by the team of experts, through the IDM (2nd stage); and finally, and if needed, a participatory process can occur depending on what the experts team has achieved (3rd phase).

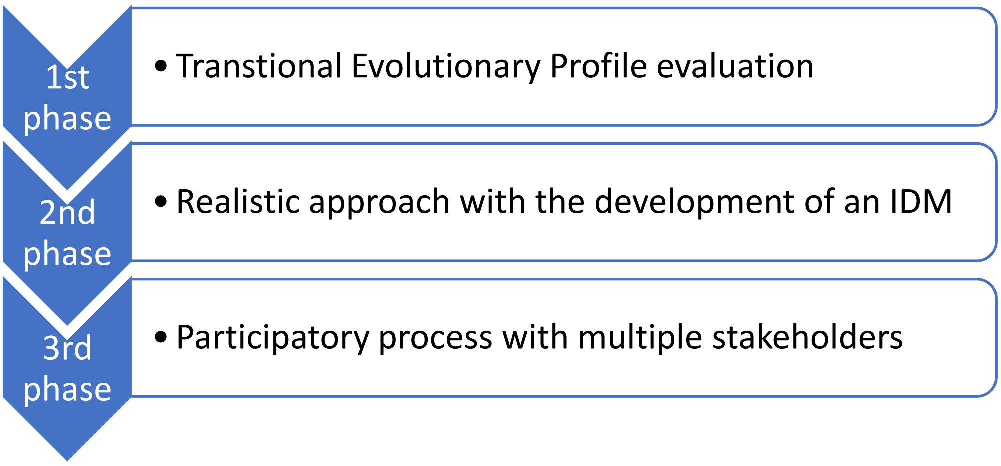

Figure 5-2: *Proposed process for the approach of ReviRIS tool (own production)(Chakhar & Mousseau, 2008)(Chakhar & Mousseau, 2008)*

The **1st phase** is mainly to allow for a comprehensive analysis of the mine site and understand what still needs to be done. With this first understanding of the type of profile, is possible to define an approach that will guide the gathering of data and the designing of alternatives. To understand which could be the site's profile, a few questions can be developed with pre-established answers, which will guide the user to find the proper profile type.

The **2nd phase** is to be implement after all alternatives are designed or at least considered, because in this phase, the experts will need to have realistic data to feed the IDM, using GIS a support to the spatial characteristic of the problem. The data they will use in the IDM are the performance values, the thresholds, and the constraints, that will serve to evaluate the criteria in each specific alternative. After that process, the chosen MCDM (according with 1st phase) will be run; the experts will assess the results and proceed to the sensitivity analysis, which consists in the modification of data according to the “what if” possible scenarios, and then make a new assessment. The IDM must be built according to the desired MCDM (AHP, PROMETHEE; ELECTRE; SIMUS, etc.) because the mathematical procedures are specific to each of the method.

Finally, the **3rd phase** corresponds to the phase where all stakeholders should be involved. The main driver for this phase is the MCDM partitioner, that must be someone with deep knowledge about the method applied, about post-mining issues, and with good communication skills, because he will be the one making the bridge between what the experts say it is possible with what the community desire. To this 3rd phase, can be brought a set of the best feasible solution that came from the 2nd phase, instead of one. This phase is also possible to be used in public consultation, where there, using the model with all the data, is possible to demonstrate the reason for the choice of an alternative.

From these three phases, the ReviRIS tool should focus mainly on the 1st and 2nd phase, because the 3rd relies strongly on the way of leading a MCDM session.

Between the 1st and 2nd phases, the objectives given in the questionnaire can be considered, because the definition of the alternatives can be having as main goal the functions for the new land uses, and the adaptation to possible climate change impacts that may be foreseen for the region.

6 CONCLUSIONS

PMLU can be considered as a complex land planning problem, with environmental concerts, and affecting local communities. For this reason, a proper methodology for decision making process regarding this topic must be developed.

The proposed methodology in this report consists of three phases, as follows:

1st phase: Transitional evolutionary profiles selection
2st phase: Initial Decision Matrix development, with GIS data and experts' knowledge to support the information
3st phase: Participatory process or public consultation

The focus of ReviRIS tool should be the 1st and 2nd phases, where there are still many different aspects to be considered in the decision process. Regarding the 3rd phase, although it is highly important when dealing with communities as stakeholders, it relies strongly on the skills of the MCDM partitioner.

In the transition from the 1st phase to the 2nd, the alternatives should be developed considering the functions for the new land uses, which, in turn, can take into account the adaptation of the regional to climate change impacts.

In Chapter 2 several MCDM are briefly described, however there are many others that can be considered in ReviRIS methodology, as is the case of SIMUS, Choquet Integral, PROBE, SAW, EDAS, ORESTE, Entropy, DEMANTEL, among others. As referred, the choice for one MCDM must consider the complexity of the site and the alternatives designed to it.

After the selection of the MCDM, the experts will use their knowledge, the data gathered through the designing of alternatives and the GIS capabilities to find the most realistic performance values that will be used in the IDM.

Summing up, the methodology that WP3 proposes for ReviRIS tool is as outlined in ***Figure 6-1***.

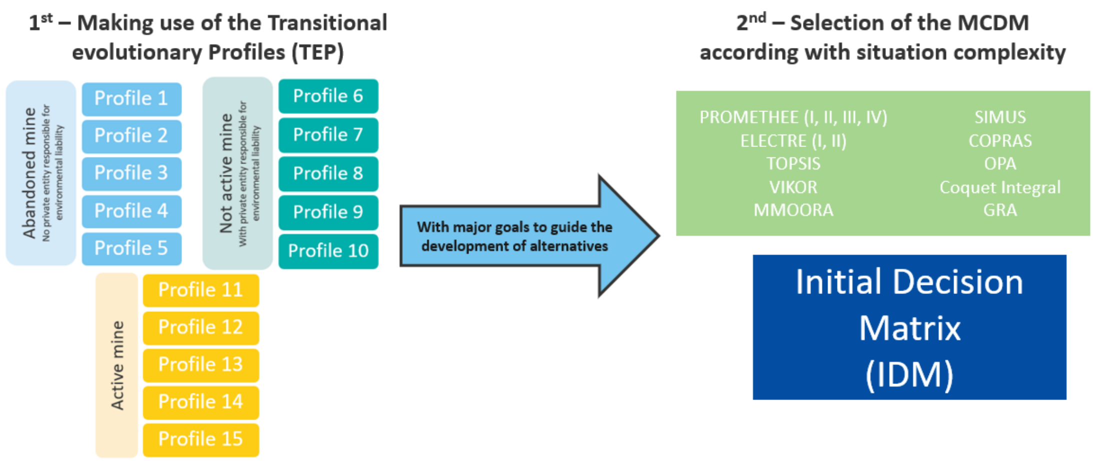

Figure 6-1: *Proposed methodology for ReviRIS tool (own production)(Chakhar & Mousseau, 2008)(Chakhar & Mousseau, 2008)*

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