Strategic Environmental Assessment (SEA) and Multi-Criteria Analysis: An Integrated Approach

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Abstract With the aim of enhancing the level of sustainability of plans and programmes adopted by local, regional and national authorities, the European Commission (EU) has adopted the Directive 2001/42/EC on the assessment of effects of plans and programmes on the environment. Starting from the analysis of strengths and possible uses of Multi-Criteria Analysis (MCA) and the investigation of its application in combination with the SWOT Analysis and the Stakeholder Analysis, the paper aims at presenting a multi-methodological approach based on the use of MCA for Strategic Environmental Assessment (SEA). Given the spatial nature of the decision problem the multi-methodological approach is moreover combined with Geographic Information System (GIS). The Multicriteria-Spatial Decision Support System (MC-SDSS) proposed is able to support the decision-making processes in the field of environmental management by providing evidence and increasing the level of choices' transparency and legitimacy.

Keywords SEA · Multi-criteria analysis · Multi-methodological approaches

1 Introduction

The instance of improving choices' legitimacy and transparency in the field of environmental management, is one of the reason that has inspired the European Commission (EU) to adopt the Directive 2001/42/EC on the assessment of effects of plans and programmes on the environment. With the aim of enhancing the level of sustainability of plans and programmes adopted by local, regional and national authorities,

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the Strategic Environmental Assessment (SEA) Directive has defined a detailed procedure based on the following steps: (i) preparation of a report where possible effects on the environment are detected and solutions and strategies identified; (ii) public consultation about the proposal identified and the report; (iii) transboundary consultations and implementation of the proposal; (iv) decision phase where the results of the consultations are evaluated; (v) information about the decision taken and the proposal adopted; (vi) monitor of the effect on the environment; (vii) compliance of other legislations (Article 3).

Since a policy aimed at supporting citizens and stakeholder involved cannot be based only on producing evidence (De Marchi et al. 2016), but it should imply the use of evaluation methodologies able to guide in the decision-making process, it is evident as the SEA Directive is not the answer but it is a starting point. In fact, as already discussed by Partidario (2000) and Torrieri and Batà (2017), the SEA can be considered more as a steering than a prescriptive framework aimed at promoting good practices.

Given these premises a multi-methodological approach able to take into consideration all the aspects involved in the environmental assessment and to satisfy stakeholders with different and sometimes conflicting interests and visions is suggested. This kind of approach is aimed to provide a deep knowledge about the territory under investigation (Oppio et al. 2016; Dell'Ovo et al. 2018) by considering all the dimensions of the sustainability aimed at resulting with an overall evaluation of the project proposed. With this purpose, the study proposes an integration of Strategic Environmental Assessment (SEA) with Multi-Criteria Analysis (MCA) based on a comprehensive modelling both of the decision problem and of the decision context. In detail, the paper is divided into four sections. In the first one an overview about strengths of the MCA is given and possible integrations with other methodologies presented; the second is focused on investigating how other scholars have combined the use of MCA for SEA; the third part provides operational recommendations and the fourth draws the conclusions by putting in evidence the advantages given by the use of integrated decision support systems.

2 Multi-criteria Analysis and Decision Processes

Multi-criteria Analysis have been developed in order to support decision makers (DMs) and to help them to take better decisions (Roy 1990). The MCA has been considered as a revolution in the field of the Operational Research (Roy 1985) given by the possibility to study all the dimensions involved in the decision process and to evaluate them individually or as part of a unique system. The complexity given by the multidimensional nature of real-world problems, the need to involve stakeholders belonging to different categories and the instance of transparency and legitimacy of processes where the final decision is going to affect the whole community (Bonte et al. 1997, 1998; Janssen 2001), bring to light the importance of decision support systems able to guide the DMs. In particular, in the public sector and in the field of

SEA this task is even more important and many multi-dimensional models have been developed able to combine different disciplines and approaches. Below an overview of MCA's strengths is presented, underlining its possible uses with a focus on SEA.

2.1 Multi-criteria Analysis: An Overview

When does rise the necessity to be supported in taking a decision?

A decision problem exists when there is a difference between a current state and a desired state (Keeney 1996) and it is characterized by some key elements: (i) there are different actors involved with different opinions; (ii) more than one alternative is able to solve the issue defined; (iii) different criteria, both qualitative and quantitative, have to be taken into consideration to better describe and compare the potential courses of action under investigation.

Considering the first topic concerning the presence of (i) multi-stakeholders with different needs and expectations, according to de Almeida and Wachowicz (2017), these kind of decisions are more challenging compared to the individual ones, since in addition to the existence of conflicting objectives, different viewpoints and preferences have to be taken into account. The (ii) generations or identification of alternatives could be defined as another decision problem, since commonly, they are considered as "given" even if, in most of the cases, they are reviewed or defined during the process and not only at the beginning of it (Ozernoy 1985). Moreover, alternatives, in order to be evaluated, have to be well defined and described by the use of (iii) criteria. Criteria are the translation of relevant objectives, what it worth to be achieved by changing the current situation. The incomparability is detected when qualitative and quantitative criteria are both present in the decision framework or when the quantitative ones are described by different unite of measurement (u.m.) and then it becomes impossible to aggregate different performances (Janssen et al. 2000).

Given this premise, the MCA is considered as a strategic tool since it encompasses a series of techniques aimed at comparing alternative projects, by considering heterogeneous measures (Roy and Bouyssou 1995; Figueira et al. 2005) and evaluating at the same time different perspectives. Some of the most common steps of MCA are:

(a) the problem structuring that allows to identify an appropriate set of criteria by structuring and prioritizing the objectives detected (Roy 2005; de Almeida et al. 2016) by SWOT Analysis and Stakeholder Analysis;
(b) the generation of alternatives able to solve the problem previously modelled. Alternatives cannot be identified a priori but only after the definition of the objectives, otherwise shall be not satisfying (DCLG 2009; Keeney 1996);
(c) the standardization procedure that is able to transform incomparable criteria in a common, uniform and dimensionless scale, using (usually) a range from 0—the

worst performance—to 1—the best performance—in order to be easily evaluated. Many methods have been developed to perform this procedure (Hwang and Yoon 1981; Voogd 1983; Massam 1988; Malczewski and Rinner 2015) and it is important to underline how already in this phase the value functions resulted from the standardization represent the DM's preferences;

(d) the criteria weight elicitation aimed to take into consideration the different points of view of the stakeholders engaged in the decision process and to assign a different influence (weight) to criteria involved in the process according to their relevance in achieving the final aim of the evaluation (Riabacke et al. 2012);

(e) in relation to the decision context and to the typology of criteria considered, the aggregation allows to combine weights and standardized performance to result in overall values, for identifying the most suitable solution (choice problem), sorting (classification problem) or ranking (ordering problem) the available alternatives (Meyer and Roubens 2005; Malczewski and Rinner 2015). Many different aggregation rules exist and the main important difference is between compensatory and non-compensatory methods. In the first case, data are aggregated and negative performances are compensated by good performances. In the second case a threshold is defined for each criterion: if the performance does not satisfy it, the alternative under evaluation is then rejected.

2.2 How to Combine Multi-criteria Analysis Within Multi-methodological Approaches

Nowadays the Multi-criteria Analysis is more and more considered as an important procedure in combination with other methodologies to support DMs in structuring the decision problems (Marttunen et al. 2017) and in taking the final decisions. The SWOT—Strengths, Weaknesses, Opportunities, and Threats—Analysis, for example, is a strategic technique for planning since it gives the opportunity to recognize criticalities and potentials able to result in strategies. Grošelj et al. (2016) proposed a two-step approach based on SWOT analysis and Analytic Hierarchy Process (AHP—Saaty 1980) for the forest management and in detail for the comparison of possible future scenarios. Also Miyamoto et al. (2014), for the flood risk management, has combined MCA and AHP-SWOT to rank interventions and evaluate the most urgent one by developing quantitative methodologies.

Since different stakeholders are involved in the process and are affected by it, it is important to identify since the early stages of the decision process which actors are going to participate and which is their role. Della Spina (2018), with the aim of designing complex urban scenarios in support of strategic planning and urban regeneration, has integrated a multi-dimensional and multi-level approach. In particular, to define the most suitable alternatives has combined the MCA with the Stakeholder Analysis in order to elicit objectives and values of the actors involved. Ianni and

Geneletti (2010) to select forest restoration priority areas has integrated the Stakeholder Analysis with the MCA too. The Stakeholder Analysis brought two benefits in the case study analysed by the paper, the first one concerns the identification of all actors involved in forest use and management and the second one is the description of expectations of beneficiaries of Forest Landscape Restoration.

Another possible implementation of the MCA regards the combination with Geographic Information System (GIS). For example, Singh et al. (2018) integrated these two methodologies to delineate groundwater potential and, in detail, GIS allowed to handle a large amount of spatial data. Moreover, Torrieri and Batà (2017) have proposed to combine GIS and MCA to contribute to the SEA from a methodological perspective and to support the generation of urban planning scenarios. The further support detected by the use of spatial data concerns the evaluation of impacts under a multi-dimensional point of view and the possibility to map the results of the analysis with a comprehensive and clear representation even for non-expert actors.

3 The Use of the Multi-criteria Analysis for Strategic Environmental Assessment (SEA)

According to what it emerges from the previous section, the use of the MCA in the field of the SEA could be strategic in order to provide a deep knowledge of the decision context, to elicit objectives and expectations of stakeholders involved in the process—both direct and indirect—and to evaluate potential plans and programms.

At this stage a literature has been framed and, as suggested by Prasara and Gheewala (2017) and Moghadam et al. (2017), it has been structured according to the following four-stages:

1. "*Literature search*": selection of a database to develop the analysis;
2. "*Screening process*": selection of keywords to narrow the analysis;
3. "*Selection of literature*": selection of papers according the aim of the analysis;
4. "*Including literature*": selection of data to detect by the analysis of the papers.

Considering the framework proposed, (1) the Scopus database has been used and the research has been based on the selection of the following (2) keywords "Strategic Environmental Assessment" and "Multi-criteria Analysis" or "MCA" to narrow the analysis. (3) 18 documents have been identified and judged suitable, according to the title and abstract, to be further studied. The analysis has been focused on (4) understanding in which SEA context the MCA has been developed; which decision problems have been faced and if within the decision process have been combined the methodologies described in the previous section: SWOT; Stakeholder Analysis and GIS (Table 1).

Bobylev (2006) has evaluated the environmental impacts of Urban Underground Infrastructure (UUI) development policies using the MCA and stressing the necessity to incorporate it in cities' masterplans. Also other scholars have investigated the same

Table 1 Literature review

Author	Year	Country	Context	Decision problem	SWOT	Stakeholder analysis	GIS
Bobylev N.	2006	Japan	Infrastructure	Multi-criteria analysis (MCA) for evaluating environmental impacts of UUI development polices	No	Yes	No
Celik M. et al.	2008	Turkey	Environmental Management	Approach based on Fuzzy Axiomatic Design (FAD) to assign suitable MCA technique during execution process of ANSEA.	No	No	No
Olazabal M. et al.	2010	Spain	Environmental Management	Integrated approach to sustainable spatial management based on the development of an integrated decision-support system	No	Yes	Yes
Cerreta M. and Toro P.D.	2012	Italy	Planning policy	The ISA approach to improve the transparency of evaluation process and evaluate planning choice for Cava de' Tirreni (Italy)	Yes	Yes	Yes
Lanado E. et al.	2010	Italy	Participatory process	Presentation of AMACI software to perform the Strategic Environmental Assessment of the local planning process of the Municipality of Trezzo sull'Adda (Italy)	No	Yes	No

(continued)

Table 1 (continued)

Author	Year	Country	Context	Decision problem	SWOT	Stakeholder analysis	GIS
Garfì M. et al.	2011	Brazil	Environmental Management	Contribution of AHP in two stages of SEA procedure applied to water programmes in developing countries	Yes	Yes	No
Azzellino A. et al.	2011	Italy	Renewable Energy	MCA to evaluate the best location for Wave Energy Converter installations	No	No	Yes
Schetke S. et al.	2012	Germany	Environmental Management	Innovative MCA of greenfield and infill sites to evaluate their sustainability and resource efficiency	No	Yes	Yes
White L and Noble B.	2012	Canada	Energy	A strategic environmental assessment (SEA) framework for electricity sector planning is developed and applied to evaluate electricity supply scenarios	No	Yes	No

(continued)

Table 1 (continued)

Author	Year	Country	Context	Decision problem	SWOT	Stakeholder analysis	GIS
Buchala Bicca Oliveira et al.	2012	Brazil	Sectoral Planning	Determining an Index of Sustainability of Expansion of the Sugar and Alcohol Sector (IScana), employing the fuzzy logic and AHP to aggregate the indicators generated in the baseline step of the SEA process, in order to consolidate a sector monitoring tool.	No	No	No
Vukicevic J.S. and Nedovic-Budic Z.	2012	Ireland	Planning policy	Integration of SEA into the planning process based on GIS multi-criteria analysis to identify potential impacts of planned activities on the environment	Yes	No	Yes
Naddeo V. et al.	2013		Environmental Management	Innovative integrated methodology for SEA, able to implement engineering aspects – mostly related to forecasting models and evaluation of impacts on the environment – as well as social issues, as to understand economic implications	Yes	Yes	No

(continued)

Table 1 (continued)

Author	Year	Country	Context	Decision problem	SWOT	Stakeholder analysis	GIS
Thompson UC et al.	2013	Canada	Infrastructure	Investigating the level of harmonization between SEA, PPP and proposed projects and their possible alternatives (CAPPP) analysing the Turcot Interchange redevelopment project	Yes	Yes	No
Capolongo S. et al.	2016	Italy	Health	Approaches to include health issues into land use plans and urban development projects and development of a tool able to provide hygiene and health evaluation of urban plans	No	No	No
Sizo A. et al.	2016	Canada	Planning policy	An approach to SEA to support PPP development and implementation for urban wetland conservation	No	No	No
Karlson M. et al.	2016	Sweden	Infrastructure	Methods for the integration of important ecological and geological sustainability criteria for planning of transport infrastructure corridors in a systematic and transparent way	No	Yes	Yes

(continued)

Table 1 (continued)

Author	Year	Country	Context	Decision problem	SWOT	Stakeholder analysis	GIS
Sharma S. and Geerlings H.	2017		Infrastructure	New methodological approach Sustainability Benefits Assessment in Urban Transport Project Appraisal (SBA-UT),	No	No	Yes
Torrieri F. and Batà A.	2017	Italy	Environmental Management	The potentiality of the ISMDSS to evaluate the impacts of different scenarios with the aim of developing a sustainable urban municipal plan	No	Yes	Yes

context. Thompson et al. (2013) tried to solve the gap between SEA, governmental plans, policies and programmes (PPP), and environmental impact assessments (EIAs) by proposing a Compliance Analysis for PPP (CAPPP) method to be applied to the Turcot Interchange redevelopment project. Karlson et al (2016) used the spatial multi-criteria analysis (SMCA) techniques for planning railway corridors based on ecological and geological criteria, while Sharma and Geerlings developed a new approach based on a systematic assessment of sustainability benefits of a project. Moving to the environmental management field, Celik et al. (2008) developed the Analytical Strategic Environmental Assessment (ANSEA) framework to overcome the criticalities detected in the traditional SEA procedure, with a special attention to the strategic decision-making levels. In fact, the ANSEA operational framework provides a contribution to the formulation of policies, programs and planning activities and it has been integrated with Fuzzy Information Axiom (FAD) methodology to select suitable MCA techniques in relation to the problem. Even if the decision context is the same, Garfì et al. (2011) has used MCA (in detail the AHP) for strategic environmental assessment of water programmes in Brazil, while Schetke et al. (2012) to develop sustainable strategies of housing development. Naddeo et al. (2013) has focused the attention on framing an integrated approach for SEA. Still changing the decision context, Olazabal et al. (2010) and Laniado et al. (2010) stressed more the participatory processes beyond the sustainable decision-making process management. Their tools, in fact, are aimed to involve from the early stage different levels and categories of stakeholders improving the communication and the transparency of the overall evaluation process. In the first case the purpose was to evaluate the urban plan of a sector under development located in the province of Araba (Spain), while in the second case the purpose was to support the SEA of the Town-Planning Scheme of the Municipality of Trezzo sull'Adda (Italy). Finally, another interesting aspect to be taken into consideration in the definition of SEA is the health issue, in particular for urban development plans. In fact, for Capolongo et al. (2016), urban planning is a form of risk prevention and nowadays SEA procedures rarely consider this perspective.

From the literature it is possible to underline that:

- many fields are covered by the SEA procedure;
- the MCA is considered by most of the selected studies as an important support to evaluate possible development scenarios and in particular their effects;
- this kind of procedure is open to engage citizens and stakeholders and, thus, to improve the transparency of decision-making processes;
- most of the analysed papers involves the use of GIS;
- only few scholars previously have combined the SWOT Analysis within the SEA procedure;
- the Stakeholder Analysis is considered as a fundamental phase to deeply understand the decision problem since allows to clarify the role played by different actors and their expectations.

4 Operational Recommendations to Develop a Multi-methodological Approach for SEA

Once analyzed the literature review and understood the advantages of combining the MCA with other methodologies, it is possible to develop a Multi-methodological Approach and operational recommendations to frame the SEA procedure. In detail, a flowchart is proposed in order to better explain the different steps aimed to strengthen its potentials as an integrated decision support system (Fig. 1).

From Fig. 1 it is possible to deduce how a great importance has been assigned to the preparatory activities leading to the evaluation as the SWOT Analysis and the Stakeholder Analysis. Both of them contribute to develop a cognitive framework and to elicit fundamental objectives in order to solve the decision problem.

The complexity given by the presence of multiple and sometimes conflicting objectives in urban transformation, and the necessity to take into consideration at the same time needs of actors directly or indirectly involved in the decision problem, suggest to frame a Multicriteria-Spatial Decision Support System (MC-SDSS) able to combine the potential of GIS—collecting, elaborating and representing on the map spatial data—with those of MCA—able to support decision-making processes through the elicitation of both qualitative and quantitative objectives and to evaluate possible impacts of the decisions taken (Malczewski 1999). MC-SDSSs allow to consider at the same time different territorial dimensions—economic, environmental, social, etc.—and to visualize them at a spatial level, in order to structure and manage the decision problems concerning integrated planning. A system based on criteria, sub-criteria and indicators spatially represented by a GIS software, opportunely standardized and aggregated according to the importance in achieving the final aim, allows to result with a synthesis map able to show potentials and the critical aspects of the territorial context under investigation. The outputs (Suitability maps) are directly connected with inputs selected according to the emerging complexity of the territory.

Suitability maps, once standardized on the basis of adequate value functions, for example, are able to point out which area is the more appropriate for the location of

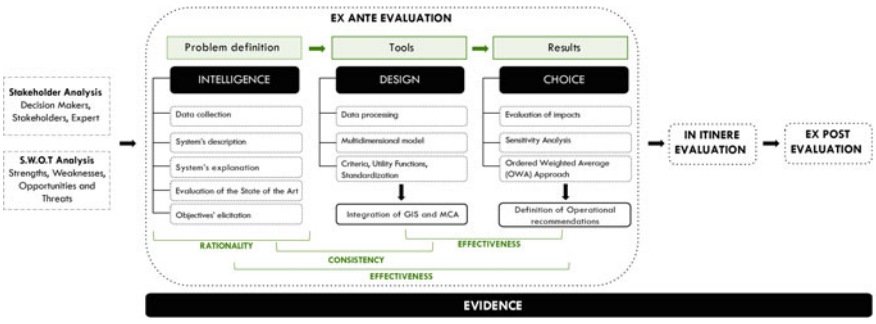

Fig. 1 Multi-methodological flowchart

services, facilities or infrastructures. It is important to underline how the strength of suitability maps is given by the possibility to read the total result (aggregated) and the partial ones (disaggregated) according to the structure of the decision problem. By providing different layers of knowledge, it is easier to comprehend precisely where are weaknesses and how to mitigate them.

Given these premises and with a special attention to strategic planning, the integration of GIS and MCA represents an effective support in the SEA field.

Considering the Multi-methodological Approach proposed, it is composed by the following phases: 1. Intelligence; 2. Design; 3. Choice. How it is possible to appreciate from Fig. 1, there is a flow of activities through the three stages and all the phases of the decision-making process involve the methodological contribution of both GIS systems and MCA techniques, in addition to SWOT Analysis and Stakeholder Analysis.

In detail, the phase 1. Intelligence represents the structure of the problem, being the system described and objectives elicited. In this context it is possible to identify criteria able to describe and to achieve the objectives detected according to the needs and expectation of stakeholders (Stakeholder Analysis) and criticalities of the territory previously analysed (SWOT Analysis) (Keeney 1992). Still within this preliminary phase of analysis, from the data collection and the system's description, problems to be solved or opportunities to take advantage of emerge (Sharifi and Rodriguez 2002). Data collected could be vector or raster and they are visualized through specific "Source Maps".

The phase of 2. Design is based on the data processing and it is aimed to develop the multi-criteria structure of the problem through the definition of the relation between objectives, attributes and DM's preferences (Malczewski 1999). The result is the "Criterion Maps". An important role is played by the standardization procedure—to make information comparable—and the criteria weight elicitation—to assign a different influence according to the purpose of the analysis. Given the spatial nature of the decisional context, at this stage, it is provided the integration of MCA with GIS systems and the definition or generation of possible alternatives and/or solutions is considered.

During the last phase—3. Choice—"Criterion Maps" are aggregated to result in "Suitability Maps" and then alternatives are subjected to evaluation. It is very useful to develop a sensitivity analysis in order to test the robustness of the model and to obtain operational recommendations. Given the multidimensional nature of the decision problem, it is strategic to evaluate the impact of each alternative defined, according to the dimensions analysed, to have a comprehensive evaluation of each scenario and, at the end, to take a decision consistently with the objectives elicited during the first phase.

Furthermore, the application of the Ordered Weighted Average (OWA) (Yager 1988) method allows to validate the feasibility of the strategies proposed, since the trade-off among criteria is considered and thresholds of acceptability of the risk are defined. The trade-off consists in evaluating to what extent a criterion can compensate another, while the risk may be defined as the probability that the decision taken is wrong. The OWA approach used in this phase becomes strategic to generate

and visualize unexpected solutions and predictive scenarios (Ferretti and Pomarico 2013).

"Evidence" crosses all the phases of the multi-methodological approach and is related to the total amount of data and information available for the DM. The Evidence can be based on facts, values, knowledge or experiences, and represents a key resource in all the phases of the decision-making process.

5 Conclusions

Considering the framework proposed and the discussion provided about the concept of Evidence, Sanderson (2002) argues about the presence of two different forms of evidence. The first one considers the effectiveness, the achievement of practical results by the work of the government, while the second is more focused about the relevance of policies and how they can work in different contexts based on specific levels of knowledge and aimed to improve social systems.

At the same time two different approaches exist to pursue the evidence (Fischer 2003; Stanhope and Dunn 2011). The first strategy concerns the proposal of transparent methodologies supported by the use of tools able to strengths phases of the decisions, the second one considers the involvement of citizens and their participation in decision-making processes by the elicitations of their expectations and interests.

By the adoption of one of the approaches proposed the final goal is the achievement of the satisfaction of actors involved and affected by the policy proposed. Also the satisfaction can be defined in two ways, both as a result and as process (Yi 1990; Grigoroudis and Siskos 2009). In the first case the satisfaction is obtained at the end of the process, as an outcome, while in the second is given by the process in relation to the perceptive feeling of fulfilment.

The concepts discussed and described in this paper suggest the definition of the evidence-based decision making (EBDM), able to synthesize the idea of evidence, defined as a fair relationship between stakeholder and DM (to brings awareness about the decision process), and as the possibility to create policies based on knowledge (De Marchi et al. 2016). The difficulty in design evidence-based policies is mainly due to the long time horizon to be effective and then measured (Sanderson 2002; De Marchi et al. 2016), even more exacerbated by delays of bureaucratic procedures.

The framework proposed in the previous section, aims to properly pursue the objectives of the EBDM by applying both strategies direct to achieve the evidence (the use of transparent tools and the participation of citizens to the decision). In fact, the whole process is supported by tools and consolidated methodologies and it is based on a deep understanding and analysis of the key actors. Within the multi-methodological approach, moreover, the concept of Evidence and satisfaction is conceived as the "result" obtained at the end of the application and, at the same time, as a "process" obtained during the development of these three phases described—Intelligence, Design and Choice—given by their complete comprehension. These kind of multi-methodological approaches, to be adopted, should be promoted by

the internal bodies of the government and integrated in planning and management policies in terms of "good practices" (Sanderson 2002).

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