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A General Morphological Analysis to Support Strategic Management Decisions in Public Transport Companies

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Abstract

This paper presents a General Morphological Analysis (GMA) meta-model aiming to help decision-makers wishing to integrate sustainability concerns into the company strategy. This is made by joining Operational Research (OR) analysts, decision-makers and stakeholders as participants in the problem structuring and formulation process. This is particularly relevant in societal issues, where public transport companies are particularly important. Indeed, public transport companies play a quite visible role in the dimensions of corporate social responsibility, namely because of four reasons: (i) they provide daily services crucial to mass customers' mobility; (ii) their investments are usually of high value and rather sensitive to technological development; (iii) they play a crucial role in the energy sector and (iv) are strongly dependent upon macro-policies.

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Keywords: General Morphological Analysis; Environmental Management; Strategic-Decision Making.

1. Introduction

GMA is a problem-structuring and problem-solving technique, designed for multi-dimensional, non-quantifiable problems where causal modeling and simulation do not function well (Ritchey, 2006). The authors consider that GMA offers an opportunity to explicitly materialize and propose a possible typology of decision-making modelling methods to approach different types of problems within the discussed context. With the help of this meta-model it is

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possible to provide the design of different ways to address problems, promoting and enhancing the transference of knowledge to and within the public transport companies. We see companies as living ‘cells’ in the economic and social structure where specific characteristics (such as learning, diversity and self-organization) must be present in order to assure resilience and sustainability when dealing with problems.

The motivation and scope of the research are presented in a diagrammatic form in Figures 1 and 2. The foundations and development of the GMA to support public transport company managers are then described and deserve a close-up detail in Table 1. Finally, two examples of application of the proposed GMA to public transport decisions are presented. These applications act as a “trigger” for further research and field tests.

MOTIVATION

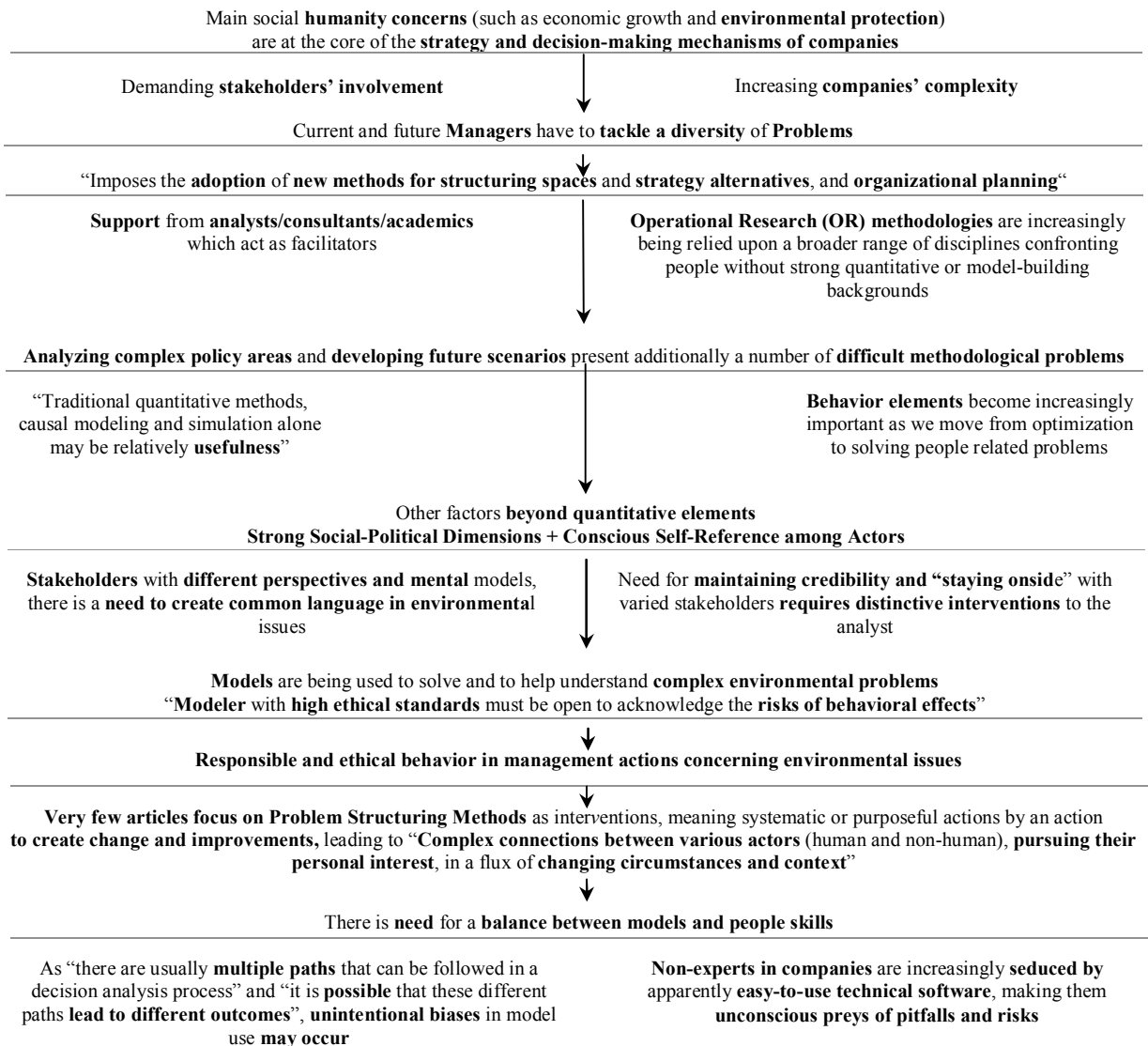


Fig. 1: Motivation of the Research

SCOPE OF THE RESEARCH

Absence of Holistic and Integrated “toolbox” for Company Decision-Makers ⇔ Construct a typology of modeling methods

Promoting the **transference of knowledge to and within companies** so that companies may assure **its resilience**

Establishing a bridge between academia and companies: “general morphology is especially suitable for OR, not the least because of the growing need for operational analysts to be part of the problem structuring and formulation process, and not simply a ‘receiver’ of predefined problems”.

Stakeholders

Context

Systemic Methodologies

GMA

Making available a meta-model based on OR in the environmental field for current and future managers of companies

Fig. 2: Scope of the Research

2. GMA

2.1. Presentation and Identification of its Parameters

The first problem is to identify the guiding vectors and properly define the dimensions of the problem - that is to say, the relevant *issues* involved. These include: Context, Stakeholders and Systemic Methodologies (see Fig. 3). “One of the advantages of GMA is that there are no formal constraints to mixing and comparing such different types of issues. On the contrary, if we are really to get to the bottom of the policy problem, we must treat all relevant issues *together*” (Ritchey, 2011). Secondly, for each issue (parameter), a spectrum of “values” must be defined. These values represent possible, relevant states or conditions that each parameter can assume.

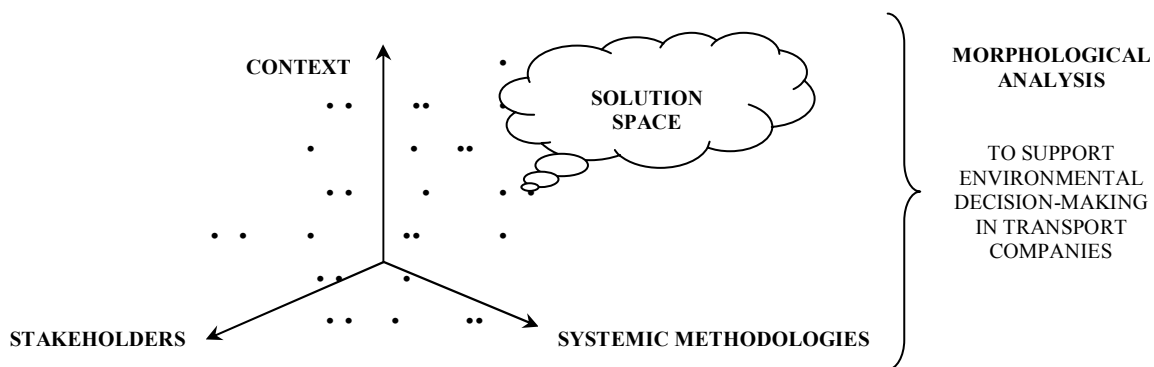


Fig. 3: The components of the GMA - dimensions of the problem

The three vectors presented in the GMA were based on the works of Jackson and Keys (1984) and Jackson (2003). The dimension related with the Context is concerned with a decision-making process for (re)designing the strategy of an organizational system. It integrates two parameters that address environmental concerns: (i) the purpose of the problem related to the integration of sustainable management decisions and (ii) their existing dominant paradigms. These two parameters are supported on the holistic approach provided by Gregory et al. (2012). The parameter “Nature of the Problem” may be classified in two broad types: objective, well-defined problems or subjective, ill-defined ones. The first type has usually an uncontested formulation, susceptible of technical solutions and that does not necessarily require the inclusion of the subjective opinion of individuals. The second type of problems usually needs to include different viewpoints of participants in order to be defined. This over-simplified classification is acceptable because the “problem nature” parameter is scrutinized in two ways. It is preceded by the parameter “Who is part of the Decision-Making Process”, which encloses in itself the dimension of Stakeholders and it will be “submitted” to an array of OR approaches. The path that will result from the definition of

the problem context and the stakeholders' involvement is determinant to provide the required inputs to explore and find the proper OR methodology.

In what concerns Stakeholders, we followed Bryson (2004) and we adopt the stakeholders' diversity of views, values and interests and their single values based on Daellenbach (2001) and Paucar-Caceres (2008). In terms of Systemic Methodologies, we have analysed methodological orientation, systems methodologies (SM) and multi-criteria decision analysis (MCDA) categories. Our primary sources of inspiration were Checkland (1981) and Schwenk (1984). In our approach, when we refer to Systemic Methodologies, we are considering not only the SM themselves, as an array of methodologies to support Decision Analysis, but simultaneously two complementary levels of analysis: at a higher level, the methodological orientation for the SM, and, at a lower level, if, by using SM, the researchers and decision-makers take into account, in an explicit way, the opinion of the stakeholders, leading us to MCDA [Huang et al. (2011) and Macharis et al. (2012)]. A more detailed version concerning the development and construction of the GMA may be found in Teles and Freire de Sousa (2016).

The GMA to be applied to transport company managers is synthesized in Table 1. This GMA contains the key parameters and their range values (selected in a mutually exclusive form) that were considered as necessary to address a wide range of alternatives for (re)designing strategies in an organizational system. The first step in the construction of a Morphological Model is to represent the parameters and their values in a matrix. The following steps consist in the application of a Cross Consistency Assessment (CCA) and in the Analysis of the Generated Alternatives.

Table 1. GMA

Purpose: Integration of Environmental Management Decisions	Dominant Paradigms: Environmental Management Decisions	Who is part of the Decision Making Process	Nature of the Problem	Stakeholder Views/Values/ Interests	Methodological Orientation (t)
Choosing a single preferred alternative	Science-based decision making	Only the owner of the problem, stakeholders eventually just informed or consulted	Simple/ Objective/ Well Defined	Unitary	Functionalist Systems Approaches
Developing a system for repeated choices	Stakeholders based decision making			Pluralistic	Interpretative Systems Approaches
Conflicting/ Coercive		The owner of the problem and other stakeholders involved in the DMP	Complex/ Objective/ Ill-defined/ "Wicked"		Emancipatory Systems Approaches
Ranking	Economic-based decision making			Conflicting/ Coercive	Critical Systems Thinking and Multi-methodology
Routing					

2.2. Pair-wise comparisons

All the presented morphological fields are submitted to judgment through a pair-wise comparison via a cross-impact matrix. The judgment of each pair-wise comparison provides an assessment among the parameters' values and also defines the level of extent of the linkages (in some cases, no linkage) between them. The use of this CCA process allows the reduction of the solution space (that contains the total possible configurations of the morphological field) to a subset of internally consistent configurations providing a smaller search. This process (also called the "analysis-synthesis process") goes from an analysis phase – centred on the development of the initial morphological field – to a synthesis phase that provides, in the end, the representation of a 'solution space'. This 'solution space' contains the generated alternative solutions. The application of CCA is useful to detect contradictions and to explore if some combinations may be (or not) appropriate. We conducted this application by using MA/Carma™. It is a computational platform that allows the analysis of the configuration produced by the

model in a more tractable and faster way, owned by the Morphological Society directed by Professor Tom Ritchey. The assessment keys used were: “-”, “K” and “X”, with the following meanings, respectively: good fit, or best fit, or optimal pair; possible, could work, but not optimal and, the last one, impossible or very bad idea. Despite the fact that these steps are being described in a sequential manner, the process is iterative. The next step is to examine and analyse the alternatives identified automatically by the computational platform. The final iteration resulted in 12 optimal alternatives and in 198 possible alternatives (including the optimal ones).

These alternatives contain different single values that are colourful. The colours code, according to the software in use, attributes the “red” colour for “input” variables and the “blue” colour for “output” variables (or parameters values). This configuration highlights an interesting characteristic of morphological models: it is possible to choose any of the single values of a parameter as an independent variable or driver. Such characteristic allows defining which are the “input” or “output” drivers, indistinctively and, therefore, to explore the diverse alternatives in an easy manner. It also permits to consider a single variable or a set of variables as “input” simultaneously and then to analyse the behaviour of the remaining variables, its outcomes, leading us to the different alternatives. This software allows to choose only the optimal paths or to choose the optimal and the possible paths simultaneously. These properties are shown in the applications for the public transport companies.

		Purpose: Integration of Environmental Decisions	Environmental Management Decisions (Dominant Paradigms)				Who - and with which role - is part of the Decision-Making Process (DMP)	Nature of the Problem	Stakeholders diversity of Views/Values/Interests	
		Choosing a single preferred alternative								
		Developing a system for repeated choices								
		Making linked choices								
		Ranking								
		Routing								
		Science-based decision making								
		Economic-based decision making								
		Social based decision making								
		Stakeholders eventually just informed or consulted								
		And other stakeholders, involved in the DMP								
		Simple/Objective/Well defined								
		Complex/Subjective/ Ill-defined/"Wicked"								
		Unitary								
		Pluralist								
		Conflicting/Coercive								
Environmental Management Decisions (Dominant Paradigms)	Science-based decision making	-	K	K	-	K				
	Economic-based decision making	-	K	K	-	K				
	Social based decision making	K	-	-	-	-				
Who - and with which role - is part of the Decision-Making Process (DMP)	Only the owner of the problem, stakeholders eventually just informed or consulted	-	-	-	-	-	-	-		
	The owner of the problem and other stakeholders, involved in the DMP	K	-	-	-	-	K	K	-	

Fig. 4. MA/Carma™: partial screen shot of cross-consistency assessment results.

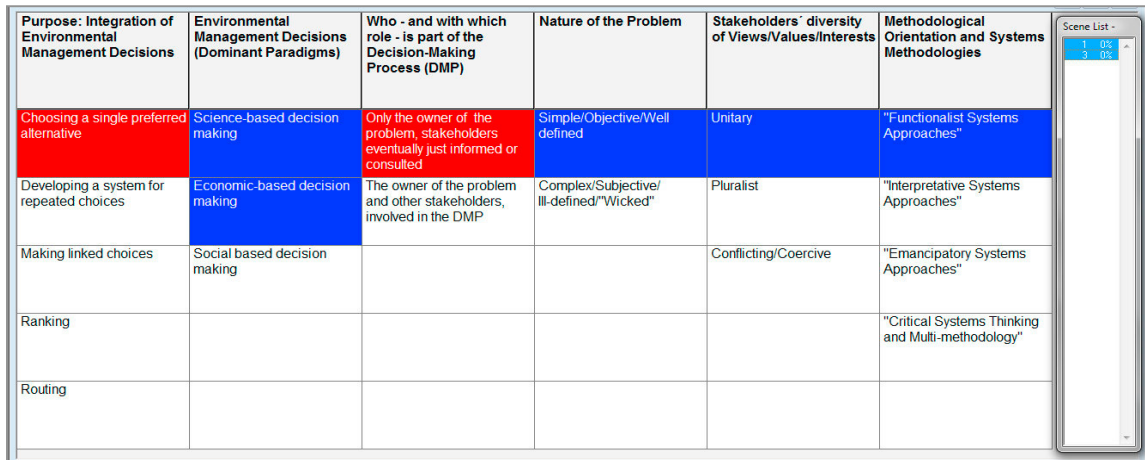
As mentioned above, all the presented morphological fields are submitted to judgment through a pair-wise comparison via a cross-impact matrix and the model is validated through a CCA using MA/Carma™ software. However, the judgmental behavior and personal preference are relevant factors to take into account and, therefore, they deserve to be analysed and discussed in a more detailed way. So, the results presented in Fig.4 were derived based on the authors’ judgmental and personal values. But, such assessment could be the result of judgmental and personal values of an individual or from an extended workshop with stakeholders. And, taking this into account, we decided to present our personal beliefs in the pair-wise comparison process with the purpose of making available a complete development of a GMA to Support Environmental Management Decision-Making in the Transport field/sector, as a prototype. One of our primordial purposes is to promote and enhance the transference of knowledge to and within the transport companies stimulating their resilience. And by doing it, we wish to demonstrate that the “Delivery of models through software or a decision-support system can permit the model to be used by others to make management decisions beyond the timeframe of a scientific research project” as in Kelly et al. (2013), employing their own judgmental behavior and personal factor.

3. Applications for Public Transport Companies

3.1. Fleet Renewal

The first application concerns fleet renewal and it is shown in Figure 5. The shareholders of a bus company are considering the replacement of part of the existing vehicle fleet. This requires a substantial capital investment and the need to consider the associated operational and maintenance costs. The owners of the company are pondering two possibilities: to replace conventional diesel vehicles by electric vehicles or just to substitute by other conventional diesel vehicles. Electric commercial buses are presenting some advantages, such as lower operating and maintenance costs and contribute to reduce the dependence on fossil fuels. They have potential to reduce greenhouse gas emissions, what is particularly relevant in urban areas. However, they are dependent on the battery autonomy which has implications, namely, on the provision of quality service to passengers. And the initial investment in an electrical fleet is higher than the initial investment in a conventional diesel fleet. In both cases, there will be an improvement on the reliability of the buses operations, benefiting the company, the customers, local authorities and regulatory bodies. For this reason, the shareholders decided to be the only owner of the problem and that they will just inform these stakeholders of the decision they had made.

According to the description of the problem situation, it is possible to follow different paths throughout the GMA. In fact, two key parameters are already “fixed”: the parameter related to “Integration of Environmental Management Decisions” and the parameter concerning “Who is part of the Decision Making Process”. The parameters value selected are, respectively, “Choosing a single preferred alternative” and “Only the owner of the problem, stakeholders eventually just informed or consulted”. These parameters are “red” color because they are “input” variables. The process of exploring the different paths (optimal or optimal and possible simultaneously) may be explored in the solution space. In this case, we have a total set of twelve paths: two optimal paths (Fig. 5) and ten more possible paths. This is helpful in making available different ways to address problem thinking and framing.



Purpose: Integration of Environmental Management Decisions	Environmental Management Decisions (Dominant Paradigms)	Who - and with which role - is part of the Decision-Making Process (DMP)	Nature of the Problem	Stakeholders' diversity of Views/Values/Interests	Methodological Orientation and Systems Methodologies
Choosing a single preferred alternative	Science-based decision making	Only the owner of the problem, stakeholders eventually just informed or consulted	Simple/Objective/Well defined	Unitary	"Functionalist Systems Approaches"
Developing a system for repeated choices	Economic-based decision making	The owner of the problem and other stakeholders, involved in the DMP	Complex/Subjective/ Ill-defined/"Wicked"	Pluralist	"Interpretative Systems Approaches"
Making linked choices	Social based decision making			Conflicting/Coercive	"Emancipatory Systems Approaches"
Ranking					"Critical Systems Thinking and Multi-methodology"
Routing					

Fig. 5: MA/Carma™ screen shot presenting the two optimal paths in the morphological matrix.

3.2. Approaches to the Problem

- Thinking about a strategic allocation and use of resources:

The renewal of a fleet is a strategic decision which should be aligned with the company's mission, its values and objectives. The choice of the type of fleet is crucial for the company to meet its purposes (such as to deliver mobility to its clients on a regular basis). In fact, the acquisition of a new fleet constitutes a significant asset for the company and requires the allocation of financial resources with subsequent economic and environmental impacts. The

resource “capital” is thus an important resource that needs to be managed along with the other resources (such as the environmental ones). In this sense, if the company seeks to chart a path grounded on environmental concerns, managers have to ponder the trade-offs between two main resources: capital resources and the use of natural resources. Therefore the decision-makers have to manage and thus establish a balance on the resources used by company.

- Know the Business - impacts in time (past experience versus future impacts):

The renewal of an asset (as in the case of a fleet) requires (besides targeting the whole lifecycle of the fleet) to have in mind all the components that integrate the management of a vehicle fleet. Fleet vehicle management integrates a wide range of activities such as financing, maintenance planning, security tracking, fuel/electricity cost management, operations management; safety; regulatory compliance; among others. This information (collected from previous experiences) constitutes a valuable input for the evaluation of new investments and to assess the associated risks. It allows predicting improvements in productivity and efficiency, as well as in economic and environmental outcomes. And thus it constitutes an important knowledge for managing and (re)allocating resources.

In addition, the performance of a vehicle fleet is determinant to ensure that a prompt and reliable service is delivered to customers based on an efficient and economical management, but it is also desirable that it incorporates (in a continuous and progressive way) the reduction of environmental impacts. In sum, it is crucial to “optimize” the fleet performance. However that “optimization” depends on personal views and values of the shareholders (the “owners” of the capital “resource”) and that have to define the balance between the allocation of capital and the use of natural resources (environmental impacts).

For these reasons, the paths presented in Fig. 5 are science based and economic based, and the shareholders of the company are the only decision-makers in the decision-making process.

- Communicating the results of the decision:

Though, the presented strategic decision is included in a process where the participation of stakeholders is absent. However, to “conquer” that absence, it might be advantageous for the company (and for the society as a whole) to communicate, in a due way, the decision taken to all the relevant stakeholders. It might also be advantageous that the company informs these stakeholders about the monitoring of the financial, economic and environmental results achieved with this strategic action. In fact, giving access to these results corresponds to a transparent and ethical behaviour from the management board and might probably encourage stakeholders to support the company's strategic choice. Or, at least, the stakeholders' interest in identifying the gaps of the fleet performance may result in recommendations for its improvement and it may represent an opportunity to the company itself.

But there are other possible paths that result from considering another dimension of environmental paradigm: “stakeholders based decision making”. This possibility may exist when addressing fleet renewal. If that is the case, the selection of stakeholders to address such problem would need additional analytical tools, such as, for e.g., the power-interest matrix. This technique allows positioning stakeholders (according to their power and interest) and then help decision makers to select which stakeholders should participate (or not) in the decision-making process. In this example, internal stakeholders like the Chief Financial Officer and the Head of Transport Department should participate and, in terms of external stakeholders, suppliers, environmental associations, central or local government, creditors could be considered.

3.3. Network planning

A second application concerns the development of a network planning, redesigning the paths and the schedules, and it is shown in Fig. 6. The shareholders of a bus company are focused on the customer orientation as a crucial point in the activity of the company. Thus, they are considering the redesign of the schedules and paths in order to obtain a greater market share, capturing potential customers from the individual transport. This strategy contributes to improve urban environmental indicators. Applying this strategy is extremely delicate because it imposes changes

in a lot of internal activities of the company (from vehicle schedules to crew assignment, vehicle maintenance plan, among others). And it also has impacts on the daily activities of general public and on the operation of the activities of a city. It interferes with the policies of transport planning, land use and environmental plans of the region. Thus, the shareholders want to involve diverse stakeholders (internal and external) to assure a coordinated and efficient implementation of the new service. The diverse stakeholders include staff, unions, customers, local authorities, strategic partners (such as other transport operators or NGOs) and regulatory bodies.

As in the previous example, and taking into account the description of this transport problem situation, it is possible to come to diverse paths all over the GMA. Due to the nature of the problem situation it is admissible to “fix” two key parameters: the parameter related to “Integration of Environmental Management Decisions” and the parameter concerning “Who is part of the Decision Making Process”. The parameters values selected are, respectively, “Making linked choices” and “The owner of the problem and other stakeholders involved in the DMP”. Once again, these parameters are “red” color because they are “input” variables. And, the process of exploring the different paths is discovered in the solution space: two optimal paths presented in Fig. 6 and twenty eight other possible paths.

Purpose: Integration of Environmental Management Decisions	Environmental Management Decisions (Dominant Paradigms)	Who - and with which role - is part of the Decision-Making Process (DMP)	Nature of the Problem	Stakeholders' diversity of Views/Values/Interests	Methodological Orientation and Systems Methodologies
Choosing a single preferred alternative	Science-based decision making	Only the owner of the problem, stakeholders eventually just informed or consulted	Simple/Objective/Well defined	Unitary	"Functionalist Systems Approaches"
Developing a system for repeated choices	Economic-based decision making	The owner of the problem and other stakeholders, involved in the DMP	Complex/Subjective/ Ill-defined/"Wicked"	Pluralist	"Interpretative Systems Approaches"
Making linked choices	Social based decision making			Conflicting/Coercive	"Emancipatory Systems Approaches"
Ranking					"Critical Systems Thinking and Multi-methodology"
Routing					

Fig. 6: MA/Carma™ screen shot presenting the two optimal paths in the morphological matrix.

3.4. Approaches to the Problem

- The dynamic of the decision-making process:

The development of a new network planning imposes various consequences in different dimensions. Firstly, on market share: the habits of current and potential clients; secondly, on the activities, processes and use of resources of the company with reflections on its economic, financial and environmental performance. But both have direct reflections on the policies of transport planning, land use and environmental plans of the region. The participation of the different stakeholders will determine the environmental impacts. This description can be found in parameter value “Social based decision making” presented in Fig. 6.

The shareholders of the company face a problem with a high level of complexity grounded on a strong social component. In fact, the participation of stakeholders in the decision making process involves several actors with conflicting objectives, distinct values and behaviours. Consequently, the shareholders of the company have to embrace different challenges simultaneously (both internal and external to the company). These elements of the problem are present in Fig. 6 through four parameters values: “The owner of the problem and other stakeholders involved in the DMP”, “Complex/Subjective/Ill-defined/”Wicked” and two alternatives to Stakeholders’ Diversity of Views/Interests and Values”, which are “Pluralist” or “Coercive”. The shareholders of the company also should pay special attention to the definition of the problem boundaries, by “isolating” the need to implement (in a

predefined period) the new schedules and paths. Note that the new network planning is going to be scrutinized by several actors with conflicting interests. So, it is important to manage the initial action space of the problem, preventing the existence of future and continuous changes on that same action space. Meanwhile, it is also relevant to gather data and information before and after the implementation of this strategic option. This action allows developing higher comprehension about the potential (positive and negative) impacts that may arise later with the new strategic option. This is important because the “first dialogues” between the company and its stakeholders might have influence on future choices and might induce different consequences and directions in the strategy of the company. In short, strategic decisions, as the one that is here presented, have strong influences over time. And, in the end, have implications over the company and on its shareholders. In Fig. 6 two parameters values related to “Interpretative Systems Approaches” and “Making linked choices” are chosen.

- The importance of local stakeholders (individual users) in the decision-making process:

The introduction of a new network plan affects directly the customers of the company and their individual wishes or expectations for best personal travel. The redesign of the schedules and paths will be assessed in terms of degree of satisfaction by its users and that assessment constitutes a relevant factor (and input) for the company. In this approach, local stakeholders are selected as being relevant stakeholders to be considered in the decision-making process. They may play an active role, especially if we consider the advent of new sources in gathering data (such as cellular network, Wi-Fi or social media). It is also increasingly possible (besides gathering data), to share and exchange data between stakeholders and the transport company. This constitutes a valuable input to support eventual adjustments on the network plan (and thus to improve customer service levels). And, at the same time, it may reinforce the dialogue (and distinctive needs) among these stakeholders and the company. In other words, it may help reducing possible reluctance and resistance to the new network plan (and its subsequent adjustments) because the data is also provided by a set of individual users.

- Big and Open Data as a mean to improve communication between the company and stakeholders:

The use of Big Data and Open Data may be a way to provide a constant monitoring of the implementation of the new strategic option of the company. This monitoring may occur in other dimensions beyond the service schedule. It may cover other dimensions such as environmental impacts, land use policies and urban planning. The use of the technological resources may grant some advantages such as: (i) allowing a constant monitoring in several dimensions (e.g. service level, environmental); (ii) propitiating a cascade effect between the company and the overall stakeholder community; (iii) helping to bring together perceptions among stakeholders. The domains related with technological resources and their use in the transport field would constitute, by itself, a subject of another research. The authors’ purpose is to draw attention to the eventual adoption of technological resources by the company as a tool to manage more efficiently the communication with the company’s stakeholders.

4. Conclusions

The presentation of the GMA does not constitute itself a novelty since it has been applied in different areas of research and for several years. The distinctive aspects of presenting the current GMA rely on the following aspects: (i) it was developed with the purpose of helping decision-makers that wish to integrate sustainability concerns into a company strategy; (ii) it establishes a linkage between environmental practices, strategic objectives, and the integration of stakeholders in the decision-making process at the level of a company; (iii) and it is to be applied in a company of the transport sector. Finally, to the authors’ knowledge, (iv) there is no GMA that had covered all the phases of a decision-making process (problem definition, problem analysis and problem solving) in such a context.

It is important to stress that, from the authors’ point of view, this technique and consequent procedures are not “a” prescription to address “a” problem. Rather it must be faced as a tool that has the virtue of not eliminating or constraining (*ab initio*) the relationships between the various dimensions of a problem. And this is particularly relevant to the decision-makers or to the analyst/consultant who assists the decision-making process because the possible paths may be worked out according to the contextual problem in hand. A company that wishes to change its

status quo must adopt a holistic approach (analyse the various dimensions of the problem as a whole) and provide itself with a critical thinking. This must be the first stage for the company to follow its strategic options and to advocate the apology of a new mindset in which different decision modes must be regarded. Thus, decision makers have to be increasingly conscious that there are different forms to address problems, and that one of these forms is related with the presence (or not) of the stakeholders. The choice of which stakeholders need to participate and their degree of involvement in decision-making processes is a key question that decision-makers have to deal with. In fact, the construction of general consensus among stakeholders is not always welcome, because it might impose a cost to the process of decision-making that doesn't match the interests of the company strategy and it might be important to face a rupture, so that the company may enter into a new life cycle stage.

The suggested meta-model is, in fact, a structured process that allows different paths with diverse possible solutions and provides an audit trail, not only for decision professionals and academic but also for transport companies' decision-makers, contributing to rise their credibility and the transparency of social consequences of their decisions.

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