MULTIPLE PERSPECTIVES ON WASTE MANAGEMENT SYSTEMS: TOWARDS MORE EFFECTIVE MODELS FOR DECISION SUPPORT

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SUMMARY: In real-world problems, there is no single perspective on the complex problem matrix of stakeholders, configurations, purposes and outcomes. However in waste management, systems modeling has commonly relied on the use of optimization tools. Decision criteria are assumed to be already defined, despite the lack of involvement of stakeholders in the formulation of the problem. Problem Structuring Methods (PSMs) are a family of approaches which use the existence of multiple perspectives in order to provide a better grounded understanding of real-world complexity, and hence improved support for decision-making. Soft Systems Methodology (SSM) is a PSM which proceeds by identifying alternative versions of potentially relevant purposeful activities, and developing their respective activity models. In this paper we apply SSM to the case of Brazilian Waste Electric and Electronic Equipment (WEEE) reverse logistics systems modeling, which is currently under discussion. Results show that SSM models can support decision-makers in tackling critical issues, ranging from minimization of costs and WEEE transport through to the organization of cooperatives.

1. INTRODUCTION

A wide variety of system modelling approaches have proved to be useful tools for decision support in waste management. Risk assessment, environmental impact assessment, cost benefit analysis, multicriteria decision analysis and life cycle assessment: all of them are methods which have been used with waste management models. They can provide decision-makers with structured understanding of the problem, and help evaluate decision alternatives. In virtually all of these cases, the models implicitly claim to be objective representations of the problem situation.

But in practical reality there is no single objective perspective on real-world waste management problems. In almost all cases there is a complexity of stakeholders, each with a different perspective on the system's configuration, possible outcomes and general purpose.

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Consequently, there is in principle a case for applying support tools which have the ability to encompass multiple perspectives . This is particularly true for sustainability assessment, where managerial analyses based on waste management models with restricted perspectives can be especially problematic.

Problem Structuring Methods (PSMs) are tools designed to support decision-making in problem situations with multiple actors and perspectives, incommensurable or conflicting interests, and salient intangibles and uncertainties. They have been successfully applied both alone and in combination with traditional methods employing optimization, or other forms of quantitative analysis.

One of the most widely used PSMs is Soft Systems Methodology (SSM). Its main feature is the development of alternative models to represent the system from a range of different perspectives. Although dealing with the same problem situation, these SSM models will each describe a different set of processes seen as relevant from that particular perspective, and consequently different inputs and outputs, resources, actors and purposes. Traditional model-based waste management methods reflect only a few of the possible perspectives on the system. SSM can provide analysts and decision- makers with richer descriptions of the real-world system, allowing for a better understanding and assessment.

In this paper, we exemplify the contribution of SSM to waste management through the case of Brazilian Waste Electric and Electronic Equipment (WEEE) reverse logistics systems. These systems have recently been under discussion and development, as a result of the Brazilian National Policy for Solid Waste (PNRS), established as mandatory in 2010.

WEEE reverse logistics necessarily involves a broad range of actors, includinggovernment at different levels, manufacturers, commercial outlets, distributors, importers, waste pickers, waste management companies and recycling industries, as well as the population in general. These stakeholders between them have a wide variety of distinctive perspectives. In this context, basing decisions on models predicated on single or restricted perspectives is rather likely to lead to disagreement and, probably, to the ineffectiveness or inefficacy of the implemented system.

2. SYSTEMS MODELING IN WASTE MANAGEMENT

Morrisey and Browne (2004), in their survey paper on waste management models, found a variety of decision-support methods and tools, such as risk assessment, environmental impact assessment, cost benefit analysis (CBA), multicriteria decision-making and life cycle analysis. Shortcomings of each of these methods are described in Table 1. Most models assume that all options and decision criteria have already been identified, and that the most important stage is the evaluation of alternatives. The type of tool selected also depends both on the decision being made and on the profile of the decision-makers who are the clients for such decision-support project (Morrisey and Browne, 2004).

The authors concluded that:

- None of the published models have considered the complete waste management cycle, from prevention to disposal. Most are concerned, rather, with refining the actual multicriteria technique or with comparing the environmental aspects of WM options;
- No model examined environmental, economic and social aspects together and none considered the intergenerational effects of the strategies;
- The non-involvement of all relevant stakeholders in the decision making process is a major shortcoming;
- Important steps in decision making for municipal solid waste management are the formulation of the problem and the involvement of stakeholders (Morrisey and Browne, 2004).

Table 1. Shortcomings of traditional methods for waste management modelling

Method for Modelling	*Shortcomings*
Cost benefit analysis (CBA)	- Environmental decision-making usually involves competing interest groups, conflicting objectives and different types of information and CBA is not suitable for these decisions; - CBA allows improvements in one dimension, to compensate for deterioration in another, which is not a strong sustainability approach.
Life cycle assessment (LCA)	- LCA has not been subject to public involvement, being a specific and highly technocratic tool. Because it is incapable of dealing with health effect predictions, it has partial relevance to public deliberation; - LCA cannot predict actual effects. It is a comparative tool that reduces data to mass loading based on simplifying assumptions and subjective judgements, and hence it can add independent effects into an overall hazard score; - It cannot easily deal with localised environmental impacts which become a public priority, or with effects that cannot be quantified as outputs; - Cannot deal with time dependant impacts; - Models which consider the full life cycle are complex and very detailed, and potential users (decision-makers) often lack the expertise and data, tending to look at financial data.
Multicriteria decision analysis (MCDA)	- Allocation of weights in outranking methods (ex. ELECTRE), are not concerned with the way criteria or alternatives are selected; - The number of criteria/alternatives can be very large.

Source: Adapted from MORRISEY AND BROWNE (2004)

Those conclusions reinforce the necessity of considering stakeholders' perspectives in a proper formulation of the proble which integrates environmental, social and economic aspects.

This is a potential contribution from Problem Structuring Methods to waste management.

3. TRADITIONAL MODELING METHODS *VERSUS* PROBLEM STRUCTURING METHODS

Nowadays, decision-making, and its supporting activities of systems modeling and problem solving are immersed in a context of unprecedent complexity and uncertainty. Complexity refers to the densely interconnected networks and ramifications that cannot be ignored. Uncertainty relate to choices from other decision-makers and their consequent influences, the dynamics of those turbulent networks, unexpected and unpredictable events, and the fluidity of organisations and individuals' missions. This complexity of contemporary problems exposes the limitations of traditional decision-support methods, usually based on mathematical modeling which aim to find the 'best' solution for rather shielded and predictable decision problems (Rosenhead and Mingers, 2001).

Various authors from different disciplines have observed a dichotomy of problem structures (Rosenhead and Mingers, 2001). Their characteristics are given in Table 2.

Table 2. Wicked versus tame problems.

Tame problems	*Wicked problems*
Individual components of complex systems	Complex systems of changing interacting problems
May be solved	Need to be managed
Can be specified in consensus, do not change during analysis	Alternative types and levels of explanations and phenomena of concern
True or false solutions, judged by analyst	Good and bad solutions, judged by interested parties themselves
Relatively unimportant to society at large	Greatest human concern
Essentialy independent of individuals' views and beliefs	Importance of participants' perceptions

Source: Rosenhead and Mingers (2001)

The dichotomy of problems presented in Table 2 also suggests that a dichotomy of methodological approaches for decision-making support is appropriate (Table 3). Traditional methods, based on mathematical models for finding the *optimum*, are more applicable to *tame* problems, while Problem Structuring Methods (PSMs) are designed to support decision-making in *wicked* problems.

Observing Table 3, we can acknowledge that most waste management projects are based on the traditional modelling perspective associated with 'tame' problems. However, sustainabilty-related problems are more *wicked*, which suggests the adoption of PSMs at some level of decision-support.

Table 3. Characteristics of traditional modeling methods and Problem Structuring Methods

Traditional Modeling Methods	*Problem Structuring Methods*
Problem formulation in terms of a single objective and optimization. Multiple objectives are subjected to trade-off onto a common scale	Non-optimizing; seeks alternative solutions acceptable on separate dimensions, without trade-offs
Overwhelming data demands, with consequent problems of distortion, data availability and credibility	Reduced data demands, achieved by greater integration of hard and soft data with social judgements
Scientization and depolitization, assumed consensus	Simplicity and transparency, aimed at clarifying the terms of conflict
People are treated as passive objects	Conceptualize people as active subjects
Assumption of a single decision maker with abstract objectives from which concrete actions can be deduced for implementation through a hirearchical chain of command	Facilitates planning from the bottom-up
Attempts to abolish future uncertainty, and pre-take future decisions	Accepts uncertainty, and aims to keep options open

Source: Rosenhead and Mingers (2001)

4. SOFT SYSTEMS METHODOLOGY

Soft Systems Methodology (SSM) is a PSM which operates by developing a set of models to be compared to the real situation, in order to stimulate debate about change. As defined by Checkland and Poulter (2006), SSM is "an organized, flexible process for dealing with situations which someone sees as problematical (…) an organized process of thinking your way to taking sensible 'action to improve' the situation, and, finally, it is a process based on a particular body of ideas, namely *systems* ideas".

Figure 1 illustrates the process of an SSM application. In more detail, SSM's steps are:

- Graphical representation of the complexity of interests, values, conflicts and issues in the problem situation (*Rich Picturing*);
- Naming human activity systems which are hopefully relevant to exploration of the problem situation (*Root Definitions*);
- Building activity models (*Conceptual Models*) of those Root Definitions, which serve as logical machines consisting of a set of the essential activities required to pursue the purpose specified in the Root Definition;
- Carrying out *multilevel analysis*, by detailing specific activities within a conceptual model as Root Definitions themselves, with their own subset of activities;

Comparing activity models with the real-world situation, identifying critical differences and conducting debate about these possible changes (Checkland in Rosenhead and Mingers, 2001).

In summary, the main elements in this approach are:

- A problematical real-world situation seen as calling for action to improve it;
- Models of purposeful activity *relevant* to this situation (not describing it);
- A process of using the models as devices to explore the situation;
- A structured debate about desirable and feasible change (Checkland and Poulter, 2006).

4. RESULTS AND DISCUSSION

To explore the contribution of Problem Structuring Methods to LCSA, we carried out an application based on the case of Brazilian Waste Electric and Electronic Equipment (WEEE) reverse logistics systems. They have been currently under discussion and development, by enforcement of the Brazilian National Policy for Solid Waste (PNRS), establish by Law in 2010.

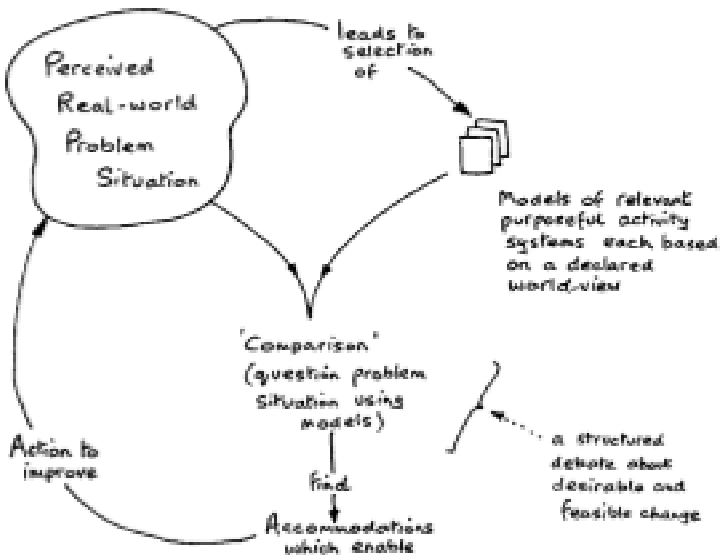

Figure 1. The Soft System Methodology cycle (Checkland, 2000)

In accordance with the PNRS, those principally responsible for the development and implementation of WEEE reverse logistics systems are: EEE manufacturers, distributors, importers and retailers. Nevertheless, the Law establishes, throughout a product's life cycle, a shared responsibility for all actors, including consumers, governments and waste picker cooperatives (PNRS, 2010).

In order to establish the WEEE reverse logistics system to be implemented in Brazil, representatives of at least the manufacturers, distributors, importers and retailers must formalize, together with the public administration at different levels, a *sectoral agreement*. Additionally, representatives of waste picker cooperatives, consumer-related entities and others can sign those sectoral agrements.

For this research, we carried out a series of interviews with stakeholders directly and indirectly involved with the development of WEEE reverse logistics systems in Brazil (Table 4).

From these interviews we developed a set of individual cognitive maps, which were then merged into a full causal map. These maps served as graphical structuring of the problem's complexity, based on real-world perspectives. Although cognitive maps are not the original form used in SSM's *Rich Picturing* step, they have been used for this purpose in some studies (Howick and Ackermann, 2011). For more information on building cognitive maps, please refer to Ackermann et al (2004).

Based on the perspectives expressed through these maps, we identified some potential relevant systems to be modeled as Root Definitions (Table 5). Each RD is characterized by a transformation process, and can be described in terms of its goals and means (a system that does "X" by "Y" in order to "Z"). We can see that ENV.01 describes a traditionally modeled system in waste management. On the other hand, SOC.01 and ECN.01 are also relevant systems that are not usually modeled in waste management, though sometimes they are implicitly considered.

Waste management systems can also legitimately be thought of as systems to generate good jobs or to aggregate value. Such systems can be as important as conventional environmental and operational processes. Modeling systems based on these alternative perspectives can therefore be highly relevant to the discussion of how the real-world situation can be assessed and improved.

In Figure 2, we present an activities model for the root definition ENV.01. As with the root definition, this conceptual model describes the way in which traditional methods "see" waste management systems, while also incorporating relevant supporting activities, such as the acquisition of resources, definition of system capacity and techonologies etc. Thinking about and trying to model "how" to carry out such activities could stimulate decision-makers to reflect on the different ways to improve their systems.

Table 4. Interviewed stakeholders

Decision-makers	State Government Environmental Agency; EEE Manufacturer; EEE Retailer
Specialists	Brazilian waste management; Reverse logistics systems; WEEE management; Brazilian environmental legislation; Regulation agency; Environmental issues journalist.

Table 5. Selected Root Definitions for system modeling

RD No.	*A SYSTEM THAT…* DOES…	BY (OPTIONS)…	IN ORDER TO…	TRANSFORMATION
ENV.01	Minimizes water contamination, air emissions and raw material depletion	Adequately recycling WEEE and disposing of residues	Minimize environmental impacts	WEEE generated → WEEE recycled
SOC.01	Generates jobs and income opportunities with adequate working conditions	Organizing, capacitating and engaging specialized cooperatives in some stages of the system, generating more economic activities and establishing a balanced model in terms of technology	Enhance social inclusion	Unemployed or informal worker → Formal worker in WEEE system
ECN.01	Makes the EEE and WEEE chain operational and economically feasible	Feeding the system with production resources, aggregating value from recycling, minimizing costs, maximizing market value for recovered material, establishing a balanced technology system	Offer good EEE prices for consumers and generate economic activities in the country	Unfeasible EEE and WEEE chain → Feasible EEE and WEEE chain
ECN.02	Enhances price competitiveness for national EEE products	Making the EEE and WEEE chain operational and economically feasible	Generate more economic activities and sell more national product	National EEE products with bad price competitiveness → Good price
POL.01	Improves government's image	Meeting WEEE reverse logistics system targets in all regions	Support reelection of government platform or members	Government's image → Improved image
ECN.03	Improves Brazilian EEE companies' image	Meeting WEEE reverse logistics system targets in all regions	Sell more national product	Companies' image → Improved image
POL.02	Meet WEEE reverse logistics targets in all Brazilian regions	Defining progressive and regionalized targets and adequately recycling WEEE	Improve governments' and companies images, and maximize material recovery and recycling	System with no targets → System with well defined and met targets
ECN.04	Aggregates value from WEEE recycling	Feeding the system with production resources, generating payback and minimizing expenses	Make the EEE and WEEE chain operational and economically feasible	Low value from recycling → Aggregate value from recycling

The cognitive maps represented the factors each interviewee used to understand the problem

Table 6 lists the main activities that feature in the activities models of just three of the root definitions. Such detailed processes can help stakeholders to identify and take account of critical activities, like "capacitate and engage cooperatives" or "assess financial and technical feasibility", which might otherwise be neglected. Some of those critical activities can be further detailed using SSM's multilevel analysis, with a focus on "how" to execute them. Multilevel analysis can generate detailed understanding on the complexity of activities needed, and then lead on to compare these models to what has been currently done. Table 7 exemplifies multilevel analysis for relevant activities within the set of RDs in Table 5.

Another contribution from the multilevel analysis is the identification of alternative ways of carrying out the same transformation. This can mean two things: the construction of alternative activity models for a same RD, each describing a different 'how' to carry out the RD's transformation; and the reflection on how each system can vary in terms of the location where processes are executed, the actors to execute them, the potential technologies etc. (Figure 3).

This detail enriches the understanding of the real system's boundaries, the complexity of processes and variables, and consequently, the potential improvements.

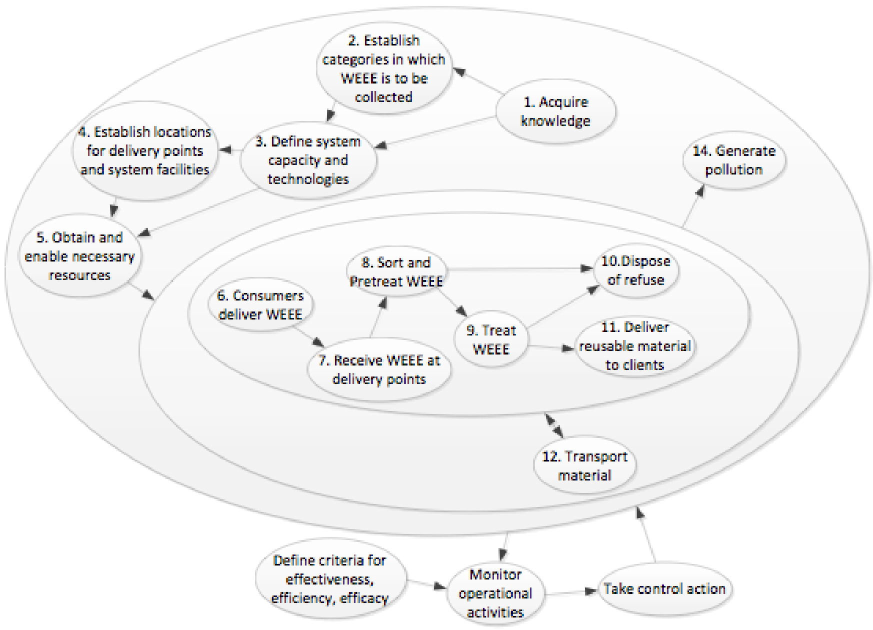

Figure 2. Activities model for the Root Definition ENV.01

Table 6. Activities within some Root Definitions' models

RD No.	*Activities*
ENV.01	Acquire knowledge; establish WEEE segregation categories; define system capacity and technologies; establish locations for facilities; obtain and enable resources; deliver WEEE (consumers); receive WEEE (stations); sort and pretreat WEEE; treat WEEE; dispose of residues; deliver recovered material to clients; transport material
SOC.01	Identify unemployed and informal workers; identify current cooperatives; analyse risks and opportunities in WEEE system; determine functions and incomes for workers; organize, capacitate and engage cooperatives; stimulate WEEE market
ECN.01	Map available infrastructure and technology; assess financial and technical feasibility; minimize system costs; aggregate value from WEEE; design and implement WEEE reverse logistics system; feed the system with WEEE

Table 7. Multilevel analysis for some Root Definitions' activities

System (RD No.)	*Activities*
Transport material (ENV.01)	Take WEEE to delivery stations; collect, transport and deliver WEEE to sorting and pretreatment facilities; transport pretreated material to treatment units; transport residues to final destination; transport recovered material to clients; consume fuel; generate air emissions
Minimize system costs (ECN.01)	Design initial WEEE system; assess initial costs; identify critical points for system costs; negotiate with suppliers; minimize taxes for the WEEE chain; optimize facilities' spatial distribution; balance workforce and technology

4.1 Discussion 1: the Brazilian reality for WEEE reverse logistics systems

The main contribution from SSM is the comparison of activity models with the real-world situation, to analyse possibilities for improvement. In Brazil, there is still no formally implemented WEEE reverse logistics system, except by individual initiatives from some companies, states or municipalities, as well as activities from the informal sector.

One of the most critical aspects of Brazilian reality regarding WEEE is the informal dimension, especially the participation of waste pickers in WEEE logistics. Some issues arise regarding this participation: exploitation by scrap dealers; health risks; informal work conditions; issues regarding quantity and quality of collected material; lack of expertise and understanding of the broad WEEE market (INVENTA, 2012).

From RD SOC.01, we can perceive some important possible ways of improving this reality. Training waste pickers, formal engagement of cooperatives within the system, or determining functions and incomes for workers, should all be implemented in order to enhance their qualification and market positioning, as well as working conditions and regularity of incomes. Issues regarding WEEE supply can be addressed by other RDs, such as ENV.01 and ECN.01.

Another issue in the current Brazilian situation is the geographic distribution of facilities and available techonology for WEEE recycling. There is no domestic specialized capacity for recycling Printed Circuit Boards (PCBs), which are usually exported either legally or ilegally, or treated in poor working and environmental conditions at scrap yards. Recycling companies capable of processing other types of WEEE component are concentrated in the country's South and Southeast regions, with very few units on the North and Northeast. This means that logistics can be a critical issue for the feasibility of WEEE reverse logistics systems.

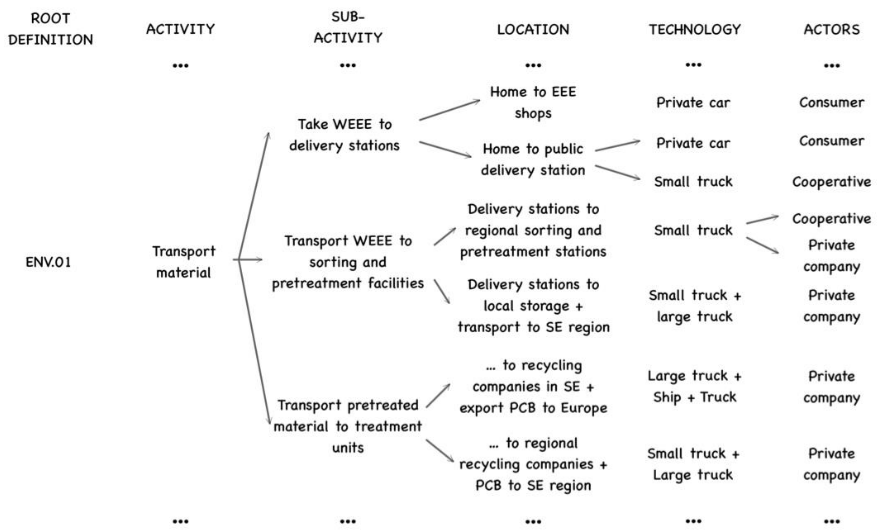

Figure 3. Possible variations for some Root Definition systems

Once again, RDs ENV.01, ECN.01 and ECN.02 can provide decision-makers with relevant insights for the improvement of the system. Multilevel analysis can produce a range of activity models and alternatives for some of the critical processes (like “transportation” and “minimize costs”), and so generate interesting potential solutions. In Table 7 and Figure 3, we can see that optimizing the spatial distribution for pretreatment and treatment facilities, and balancing workforce and technology (how technological or manual should the activities be), could be good routes to costs minimization. Financial incentives for the WEEE sector are also considered in RDs like ECN.02, as is tax reductions (Table 7) seen as a complementary means to minimize costs.

4.2 Discussion 2: the official preliminary model for Brazilian WEEE reverse logistics system

Before issuing a public call for sectoral agreements, the Brazilian Government established a Thematic Task Group (GTT), with the aim of assessing the technical and economic feasibility of WEEE reverse logistics systems in Brazil. The GTT members were the same representatives required for sectoral agreements. In order to achieve their goal, the GTT had several meetings where they discussed their different perspectives on the problem, some critical issues and the interpretation of some benchmarking cases. In the end, the GTT hired a consultancy company to develop a preliminary model for feasibility assessment.

Although the methodology adopted by the consultants involved a series of interviews of stakeholders, it was unclear how they structured and analysed those interviews to generate inputs for the system modeling. However they emerged with a set of nine decision variables, each with corresponding alternatives (Table 8). After discussing and categorizing benchmarks according to the variables, the consultants proposed a final model, represented by the selected alternatives from the options in Table 8.

Based on our previous theoretical discussion (sections 2 and 3), we can sketch some critiques of this suggested model, and the methodological steps through which it was derived. Firstly, although carrying out a series of interviews, the decision-making both for the modeling method and for the model itself was centered on the consultancy company. Stakeholders behaved more as clients hiring for a ready solution, rather than as participants in a decision-making process, and secondarily as sources of data rather than as sources of knowledge on the problem situation.

Secondly, this is not a valid system model. The selected alternatives do not describe specific processes needed to obtain each desired outcome. There is no specification on "how" the system should be configured in order to accomplish its tasks. Activity models based on Root Definition POL.02 (Table 4) can, for example, specify the activities needed to adequately accomplish "defining recycling targets", the chosen alternative for variable C in Table 8.

Finally, there is no clear description of the transformations carried out by the suggested model. What are the inputs and outputs for the system? What is being transformed, and how? In general, the model does not make clear what are the main products or services delivered by the system. The report mentions "targets", but how are those targets intended to be developed, without having clarityon what is being processed (WEEE, workforce, information, financial resources…)? SSM could be an appropriate approach to generating understanding of those resources flows, and to developing indicators for performance assessment (see Mingers et al, 2007).

Table 8. Decision variables and alternatives considered in the preliminary WEEE system model

Variables	*Alternatives (* = Selected)*
A. Sources of funding	1. Taxes; 2. Manufacturer/importer; 3*. Shared costs
B. Responsibility for "orphan" WEEE	1*. Public administration; 2. Manufacturer/importer
C. Targets for recovery and recycling	1. No targets; 2*. Recycling targets; 3. Recovery and recycling targets
D. Level of responsibility of the public administration	1. Legislator, regulator and supervisory; 2*. Active; 3. Operator
E. WEEE classification	1. Commodity; 2*. Non-hazardous waste; 3. Hazardous waste
F. Reuse within the system	1. Not stimulated; 2. Estimulated via campaigns; 3*. Enabled by the system
G. WEEE segregation according to brands	1. With segregation per brands; 2*. Monitoring and sampling; 3. Without segregation per brands
H. Proportional responsibility for WEEE	1. Individualized; 2*. Proportional
I. Competition model	1. Monopoly; 2*. Competitive (diverse management entities)

Source: Adapted from Inventa (2012)

5. CONCLUSIONS

Based on the results and discussion, we can conclude that:

- SSM could support the identification and modeling of relevant processes for the Brazilian WEEE reverse logistics system;
- Based on the results, SSM has helped to identify some potential improvements in the design of the Brazilian WEEE situation, including the spatial distribution of facilities, the balance between technology and workforce, tax reduction, and training for cooperatives.
- The preliminary model suggested is not a proper systems model, as it does not detail processes and resource flows.

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