ISO 55001 – A Strategic Tool for the Circular Economy – Diagnosis of the Organization's State

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Abstract

Circular economy arises at a time when the needs for the reduction, reuse, recovery and recycling of materials and energy need to consolidate. Today's economy is unsustainable in the short run. The standard ISO 55001 defines a set of requirements that, when implemented and maintained, guarantee the good performance of an organization's asset management, responding to stakeholder needs and expectations and ensuring the value creation and maintenance as well as a global vision of assets in a circular economy.

The organizations where physical asset management is of major importance include all those that involve: facilities, machinery, buildings, roads and bridges, utilities, transportation industries; oil and gas extraction and processing; mining and mining processing; chemicals, manufacturing, distribution, aviation and defence.

However, since ISO 55001 is a new standard in the global market, because it is intrinsically difficult to implement, a diagnostic model on the state of organizations can greatly help on the implementation.

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Before beginning to implement the ISO 55001 standard, it is necessary to verify whether the organization is ready to begin this task. It is usually necessary to fine-tune many aspects before starting a great task like this. But where to start? What aspects do I need to correct before starting the default implementation?

This paper proposes a diagnostic model to evaluate the state of the organizations in relation to their potential to implement the ISO 55001. The diagnosis allows to identify the aspects of the organization that are ready to receive the new standard, as well of the critical, the fragile and the weak points of the company that must be corrected.

The diagnostic model is based on surveys, with several questions and with five possible answers. Each possibility of response has a quantification and a critical classification.

The final result is a global positioning of the company with the identification of the various aspects to be corrected in order to be possible to implement the ISO 55001. A radar chart provides a global "radiography" of the company diagnosis.

The diagnostic template has been validated and the results are presented in the paper.

Keywords: Circular Economy, ISO 5500X, Sustainability, Industry 4.0.

1 Introduction

The linear economy model that emerged from the industrial revolution has been applied up to the present day, based on the concepts of raw material extraction, processing, and the end of life of products where they are discarded (Figure 1). This model uses exhausted materials and energy that make it clearly unsustainable in the long run - basically everything in this model becomes garbage, which will cause environmental and also social problems as well as an impact in the lives of others who are completely foreign to the process of which resulted this garbage.

Figure 1 Linear Economy [1].

In the current context, where increased consumerism and resource depletion introduces a new concept of circular economy, inspired by the natural ecosystems themselves, where everyone depends on products or by-products of others, and where resources regenerate and the cycle closes, the disposal of waste is small and all products and by-products are valued during the process, entering the chains again within the same process or others, where nothing is lost and everything is transformed.

The preceding subjects are discussed in this paper, including the proposal of a diagnostic model to evaluate the state of the organizations in relation to their potential to implement the ISO 55001, in the ambit of circular economy. This paper is structured by the following way:

- The next section makes a short resume of the state of the art;
- The section three presents a Diagnostic Model for the ISO 55001;
- The section four presents a model application to show how to use it in any company that wants to implement this standard;
- Finally, the conclusions are presented about the model and the case study.

2 State of the Art

Circular economy is restorative and regenerative by-project and aims to keep products, components, and materials with the greatest utility and value at all times. As a concept that distinguishes between technical and biological cycles, circular economy is a continuous and positive development cycle (Figure 2). It preserves and enhances natural capital, optimizes resource yields, and minimizes system risks through the management of limited stocks and renewable flows. A circular economy works effectively at all scales [2].

Circular economy offers multiple value creation mechanisms that are separate from the consumption of limited resources. In a true circular economy, consumption only occurs in effective biorhythms and, on the other hand, replaces consumption. The resources are regenerated in the bio-cycle or recovered and restored in the technical cycle. In the biological cycle, life processes regenerate disordered materials, with or without human intervention. In the technical cycle, with enough energy available, human intervention recovers materials and recreates order. Maintaining or increasing capital has different characteristics in the two cycles.

Figure 2 Circular Economy [1].

The circular economy is based on three principles, each addressing the challenges of the resources and systems facing industrial economies:

1. Preserving and improving natural capital, controlling limited stocks, and balancing flows of renewable resources. This starts by demystifying the utility by delivering them virtually, whenever possible. When resources are needed, the circular system selects them wisely and chooses technologies and processes that use renewable, or better-performing resources whenever possible. A circular economy also increases natural capital by encouraging nutrient flows within the system and creating conditions for regeneration, such as soil;
2. Optimizing the yield of resources, circulating products, components and materials with the highest utility in all technical and biological cycles. That means designing for remanufacturing, remodelling, and recycling to keep components and materials flowing and contributing to the economy. Circular systems use tighter internal cycles as long as they preserve more energy and other values, such as work done. These systems also keep the product cycle down, extending product life and optimizing reuse. Sharing, in turn, increases the use of the product. Circular systems also maximize the use of end-use materials based on biological products, extracting valuable biochemical feedstock and using them in different, lower and lower applications;

3. Promoting the effectiveness of the system, revealing and removing negative externalities. This includes reducing the harm of human use, such as food, mobility, shelter, education, health and entertainment, and managing externalities such as land use, air, water and noise pollution, release of toxic substances and climate change.

While the principles of a circular economy act as principles of action, the following fundamental characteristics describe a pure circular economy:

- Waste does not exist when the biological and technical components (or "materials") of a product are designed to fit within a cycle of biological or technical materials. Biological materials are non-toxic and may simply undergo a composting process. Technical materials such as polymers, alloys, and other artificial compounds are designed to be used again with minimal energy and high retention (while recycling, as often understood, results in a reduction of quality and becomes feedback into the process as matter – raw gross);
- Modularity, versatility, and adaptability are valued features that need to be prioritized in a rapidly evolving world. Several systems with many connections and scales are more resilient in the face of external shocks than systems built simply for efficiency, by maximizing production directed to extreme results in fragility;
- The ability to understand how the parties influence each other within a whole and the relationship of the whole to the parts is crucial. The elements are considered in relation to their environmental and social contexts. While a machine is also a system, it is strictly limited and assumed to be deterministic. Thinking systems generally refer to the overwhelming majority of real-world systems: they are non-linear, high-interference, and interdependent. In such systems, inaccurate start conditions combined with interference lead to often surprising consequences and results, which are often not proportional to the input. Such systems cannot be managed in the conventional, "linear" sense, requiring more flexibility and more frequent adaptation to the changing circumstances;
- For biological materials, the essence of value creation lies in the opportunity to extract additional value from products and materials by linking them through other applications. In biological decomposition, whether natural or in controlled fermentation processes, the material is divided into stages by microorganisms, such as bacteria and fungi, that extract energy and nutrients from the carbohydrates, fats, and proteins found in

the material. For example, going from a tree to the furnace causes a loss in value that could be availed through state decomposition by successive uses such as wood and wood products before deterioration and eventual incineration.

According to Douwe Jan Joustra (2017) there are ten key points in the implementation of a circular economy, one of which is asset management [3]. Assets are physical, but they can also involve people, information, or data. Assets are required to perform the services that are the basis of the contract with your customers. Although information and people are fundamental, in this context we talk primarily about physical assets, which can be of all kinds on the scale: a drill is one example of physical assets and oil rig as well. Asset management is critical for creating good performance. Asset management and maintenance are often considered the same. From a circular perspective, asset management goes a step further. The challenge is to use the best possible performance of the assets within acceptable risks and at controlled costs over their useful life to deliver the services within the customers' expectations. The assets are the company's capital and will be part of the resources that can be used for quality production.

What is asset management? What are assets? ISO 55000 defines asset management as "coordinated activity of an organization to realize value of assets" and assets, such as: "An asset is an item, thing or entity that has potential or real value to an organization". Asset management involves balancing costs, opportunities, and risks against the desired performance of assets in order to achieve organizational goals. This balance may have to be considered in different time frames. Asset management also enables an organization to examine the need and performance of assets and asset systems at different levels. In addition, it allows the application of analytical approaches to manage an asset at different stages of its life cycle (which can start from the design of the asset's need until its withdrawal, and includes the management of any post-withdrawal obligation). Asset management is the art and science of making the right decisions and optimizing the delivery of value. A common goal is to minimize the cost of living of assets. But there may be other critical factors, such as risk or continuity of the business, to be considered objectively in this decision making [4].

According to Jones *et al*. (2014) in the United Kingdom, the oil and gas sector identified the need for an asset management approach to physical asset management in the late 1980's. The main drivers of change were the safety management (risk) and the achievement of financial efficiency [5].

In 1988, a fire at the Piper Alpha oil rig in the North Sea, linked to the subsequent Cullen Report for maintenance problems at a pump and safety valve, killed 167 workers. This accident, combined with the dramatic drop in oil prices in 1986, focused on the oil and gas industry and on the need to adopt a holistic asset management based on a life cycle approach. This focus on asset life cycle management has resulted in improvements in efficiency, safety, and productivity in the oil and gas industry. UK water and electricity also adopted an asset management approach when they were privatized a few years later. Privatized water companies in England and Wales have also developed asset management in response to pressure regulation to minimize rate increases, while simultaneously improving the level of service provided to customers and addressing the problem of aging infrastructures. The Office of Water Services (OFWAT), the economic regulator of the water and wastewater industry in England and Wales, was created in 1989. OFWAT was initially focused on improving data quality, setting service level objectives, and monitoring compliance with service levels.

The Australian Government, which identified the need to address infrastructure management early, promoted the development of asset management during the 1980's. The Institute of Public Works Engineering of Australia developed and issued the Australian National Asset Management Manual in 1994 which introduced asset management concepts and provided guidance on their implementation. In New Zealand, the National Asset Management Steering Group (NAMS) was established in 1995 to develop and promote asset management practices in infrastructure. In 1996, NAMS issued the New Zealand Infrastructure Asset Management Manual, which was used by municipalities and water services to develop asset management plans. The Institute of Public Works Engineering of Australia and NAMS then worked together to develop the International Infrastructure Management Manual, which was first published in the year 2000. This was built on previous manuals and case studies were included.

Asset management did not develop as fast in the United States compared to the UK, Australia, and New Zealand, mainly due to the different structure of the industry. The US water industry has many organizations and a mix of municipal entities. However, some US water utilities have implemented asset management programs since the early 2000's, such as Seattle Public Utilities (SPU) in Washington and Oregon's City of Portland Water Bureau, making them two good examples. On the wastewater side, the US Environmental Protection Agency (USEPA) recognized the benefits of an asset management approach with the introduction of the Competencies, Management, Operations and Maintenance program in 2001. This program was one of the first initiatives to require a form of asset management planning in the United States.

In 2004, the British Standards Institute (BSI), together with the Institute of Asset Management (IAM), published the Publicly Available Specification 55 (PAS 55). These specifications have been very successful, with wide use in the areas of energy, transportation, mining, process, and manufacturing industries. In 2008, 50 organizations from 15 industry sectors in 10 countries worked together to launch the latest update of PAS 55, known as PAS 55: 2008. These were made up of two parts: 1. PAS 55-1: Specification for Optimized Management of Physical Assets; 2. PAS 55-2: Guidelines for the Application of PAS 55-1. The new update provided clear definitions and a set of 28 specific requirements points to establish and verify alignment, optimization and the entire system of life management for all types of physical assets. At the end of July 2009, BSI, supported by IAM, submitted a proposal to form a “Project Committee” to develop an international standard. This ISO standard would be based on the good work already done at PAS 55 and which included knowledge of other industries and scientific societies located around the world. Thus, in January 2014, under the cover of the International Organization for Standardization (ISO), the ISO 55000 family of standards for asset management was published, [7–9]. Figure 3 presents the evolution of Asset management.

3 Diagnostic Model for ISO 55001

The method of diagnosing the state of the organization for the implementation of ISO 55001 used corresponds to a set of surveys in which the evaluation of the responses indicates the position of the company in relation to the application that can be called standard. This audit method is designed to be used by members of the organization even if they have little or no knowledge about ISO 55001. Thus, it is a simple tool and easy to apply without great human resource requirements.

3.1 The Surveys

The present methodology consists of 25 surveys, which are individual and can be filled either by company staff or external consultants. For this purpose, there is a fact sheet for each requirement of the standard, which must be answered by company managers or consultants outside of the company.

Figure 3 Evolution of Asset Management, adapted from [5].

If there are doubts, each questionnaire is accompanied by a document explaining what is expected in each statement. The following table (Table 1) presents the 25 stages that make up the several questionnaires on which the diagnostic model is based, with the respective maximum and minimum scores. Those scores are related with the minimum score to implement the ISO 55001 on the corresponding stage, and the maximum score corresponds to the highest score that can be achieved.

For each of the items referred to, a diagnostic form, type survey, with several questions and five possibilities of response is elaborated, which are the following:

1. "Always" - always verified in the company;
2. "Mostly" - not always verified in the company;
3. "Generally" - sometimes verified in the company;
4. "Hardly" - rarely occurs in the company;
5. "Never" - never verified in the company.

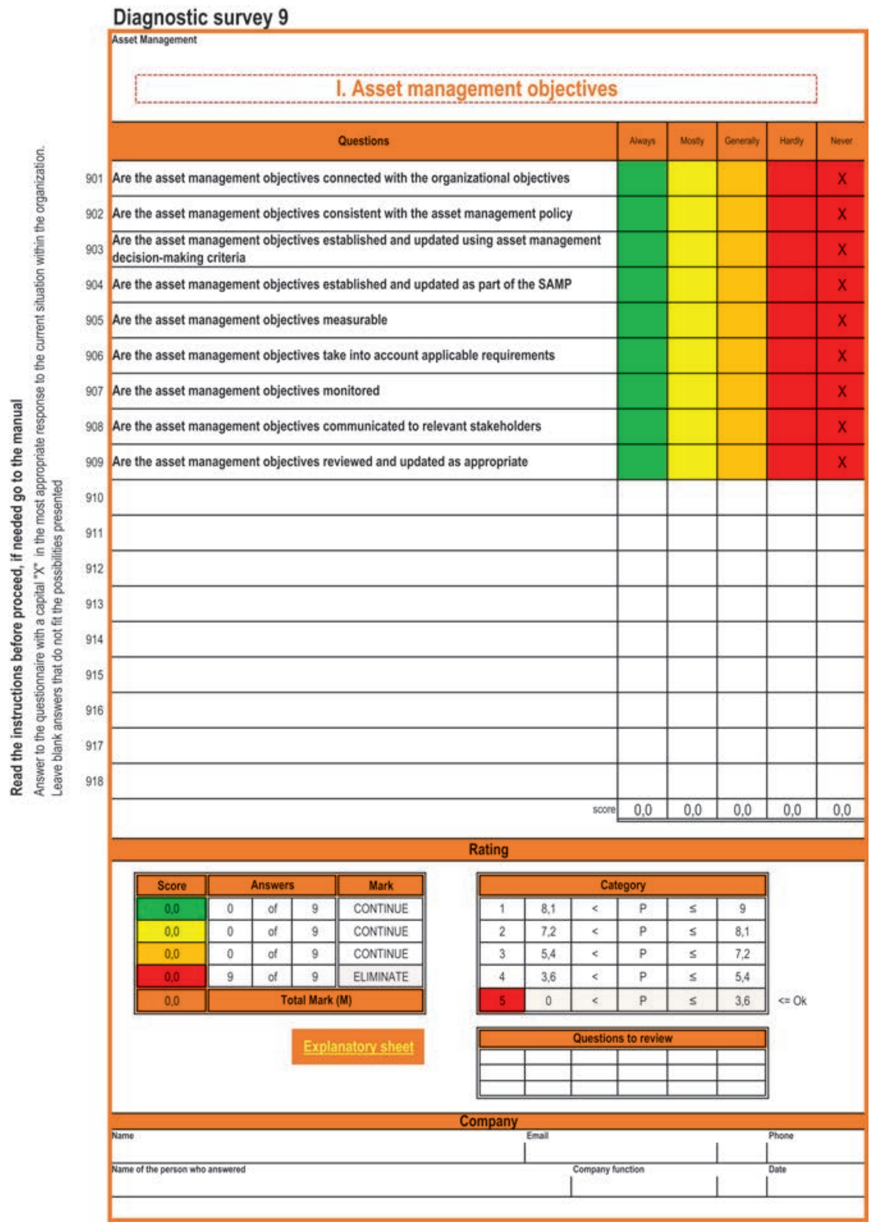
Table 1 The 25 stages of the diagnostic model, with their respective maximum and minimum scores

Stage		Surveys	Maximum Score	Minimum Score
1	A.	Understanding the organization and its context	3	2,4
2	B.	Understanding the needs and expectations of stakeholders	4	3
3	C.	Determining the scope of the asset management system	3	2
4	D.	Asset management system	2	1,6
5	E.	Leadership and commitment	17	13,6
6	F.	Policy	12	9,6
7	G.	Organizational roles, responsibilities and authorities	6	4,8
8	H.	Actions to address risks and opportunities for the AMS	5	4
9	I.	Asset management objectives	9	7,2
10	J.	Planning to achieve asset management objectives	13	10,4
11	K.	Resources	2	1,6
12	L.	Competence	4	3,2
13	M.	Awareness	4	3,2
14	N.	Communication	4	3,2
15	O.	Information requirements	12	9,6
16	P.	Documented information	8	6,4
17	Q.	Operational planning and control	4	3,2
18	R.	Management of change	3	2,4
19	S.	Outsourcing	3	2,4
20	T.	Monitoring, measurement, analysis and evaluation	4	3,2
21	U.	Internal audit	9	7,2
22	V.	Management review	9	7,2
23	W.	Nonconformity and corrective action	11	8,8
24	X.	Preventive action	2	1,6
25	Y.	Continual improvement	3	2,4

Figure 4 presents an example of a Diagnostic survey 9 “I – Asset management objectives”.

3.2 The Explanatory Sheets

In order to minimize doubts about the content and comprehension of the questions formulated in the diagnostic sheets, these are accompanied by an explanatory sheet (Figure 5), individualized by questionnaire that allows,



Read the instructions before proceed, if needed go to the manual
Answer to the questionnaire with a capital "X" in the most appropriate response to the current situation within the organization.
Leave blank answers that do not fit the possibilities presented

Diagnostic survey 9

Asset Management

I. Asset management objectives

	Questions	Always	Mostly	Generally	Hardly	Never
901	Are the asset management objectives connected with the organizational objectives					X
902	Are the asset management objectives consistent with the asset management policy					X
903	Are the asset management objectives established and updated using asset management decision-making criteria					X
904	Are the asset management objectives established and updated as part of the SAMP					X
905	Are the asset management objectives measurable					X
906	Are the asset management objectives take into account applicable requirements					X
907	Are the asset management objectives monitored					X
908	Are the asset management objectives communicated to relevant stakeholders					X
909	Are the asset management objectives reviewed and updated as appropriate					X
910						
911						
912						
913						
914						
915						
916						
917						
918						
	score	0,0	0,0	0,0	0,0	0,0

Rating

Score	Answers			Mark
0,0	0	of	9	CONTINUE
0,0	0	of	9	CONTINUE
0,0	0	of	9	CONTINUE
0,0	9	of	9	ELIMINATE
0,0	Total Mark (M)			

Category						
1	8,1	<	P	≤	9	
2	7,2	<	P	≤	8,1	
3	5,4	<	P	≤	7,2	
4	3,6	<	P	≤	5,4	
5	0	<	P	≤	3,6	<= Ok

Explanatory sheet

Questions to review

Company

Name | Email | Phone

Name of the person who answered | Company function | Date

Figure 4 Diagnostic survey.

Explanatory Sheet 1

Asset Management

A. Understanding the organization and its context

Explanatory interpretation of the question

	Always or Mostly or Generally	Hardley or Never
101	External issues that are relevant to the AMS are indentified such outsourcing our suppliers	External issues that are relevant to the AMS aren't identified
102	Internal issues that are relevant to the AMS are indentified such operating practices or equipment replacement	Internal issues that are relevant to the AMS aaren't identified
103	SAMP is conected with organization and there is a asset management thinking	The SAMP works alone and with no interaction with company organization
104		
105		
106		
107		
108		
109		
110		
111		
112		
113		
114		
115		
116		
117		
118		

Figure 5 Explanatory sheet.

question by question, interpretation of the questions and knowledge as to which answer option to indicate.

Diagnostic data sheets are identified at the top, by the number of the corresponding stage (1 to 25). The name “Diagnostic survey”, is also identified by a heading designating the corresponding stage.

There follows an intermediate zone where the grid with the questions and columns reserved for the respective answer is located. Each line begins by indicating a number associated to each statement consisting of three or four digits. The first one(s) represent(s) the number of the inquiry sheet and the other two identify the order of the statement. It is based on this numbering that you can search for help in “Explanatory sheets”. The following five possible response possibilities appear in the following columns – “Always”, “Mostly”, “Generally”, “Hardly” and “Never” – as already mentioned. One and only one option must be answered. If it is impossible to respond, then no option should be filled.

Finally, the lower part is reserved for determination:

- The score obtained;
- The consequent classification by categories;
- Elimination criteria achieved.

3.3 Organization and Analysis of Information Collected

Depending on the answers obtained in the surveys, interpretive of the current state of the organization in relation to the implementation of ISO 55001, each diagnostic record will have a certain score, which is divided into five categories: Category 1; Category 2; Category 3; Category 4; and Category 5. Within the positive situations we have category 1, synonymous with the very good positioning of the company, and category 2 that translates a good positioning. Next, a central or intermediate situation between positive and negative situations that translates a reasonable positioning. Within the negative situations, category 3 indicates that there are still aspects to be improved in the organization, while category 4 translates a bad positioning for the application of the norm, indicating that it will be necessary to carry out a broad and deep intervention of reorganization of this stage.

Thus, for each stage, category 1 is the one associated to the highest scores, synonymous of the good positioning of the company, while category 5 corresponds to the lowest scores, associated with poor performance.

Each stage must achieve a minimum score in order to sustain the positioning of the next stage, viz, the company will not be able to adequately

Table 2 Criteria of importance of the responses in the positioning of the maintenance state [6]

Green	Adequate answer This answer is always desirable.
Yellow	Inadequate answer Only some answers should be of this category and the company should improve them.
Orange	Exceptional answer Few answers should be of this type, although these responses are not eliminatory, the company should improve them as soon as possible.
Red	Critical answer The company should never have this type of answer, being the first to be reviewed.

guarantee the implementation of the questions of a given stage without the previous stage having reached a position that is considered favourable. In practice, it is established that the company must reach the threshold of the third category as a guarantee of sustainability application of the next stage.

3.4 Elimination Criteria

Each possibility of answering the several questions is assigned a degree of importance, functioning as a criterion of elimination, according to four colours (green; yellow; orange; and red) with the interpretation given in Table 2.

A withdrawal criterion is considered to have been achieved if the company has responded to a critically important question or exceeded the maximum number of allowable responses on matters of exceptional and inappropriate importance.

The evaluation of the questionnaires allows to determine the state of the company in the scope of the management of the physical assets of the organization.

It can be seen from the several questionnaires that the columns for “Always” or “Mostly” answers are the most desirable response possibilities and therefore the “green” colour of the elimination criterion is always attributed to them.

For each question answered with a negative or central form, viz, “Generally”, “Hardly” or “Never”, the template automatically produces a report of fragile points (responses obtained in orange zones) or critical point reports (responses obtained in red areas).

3.5 Elimination Grid

The elimination grids are no more than coloured cells in red, orange, yellow, and green that are part of the questionnaire grid of each diagnostic sheet. When a critical, exceptional, inadequate or adequate response has been given, respectively, it allows to identify whether the company, in this matter, has been eliminated or not, according to the process previously described, "Always" and sometimes "Mostly" gives the maximum score, on the other end "Never" and sometimes "Hardly" give the minimum scores.

The process of colour assignment in the criteria of elimination results from the importance that each question contributes to the asset's management process and, consequently, its implications to the organization's reorganization.

The score (A) obtained by the company results from the following formula:

$$A = \sum A_A + \sum A_M + \sum A_G + \sum A_H$$

Where,

- A_A – Answer "Always"
- A_M – Answer "Mostly"
- A_G – Answer "Generally"
- A_H – Answer "Hardly"

The score obtained gives origin to the category that the company achieved in each stage or questionnaire.

4 Model Application

According to Table 3 it can be seen that the score achieved by the company clearly demonstrates that many changes will be necessary for the application of ISO 55001.

This result was spectacle since it is a public institute where few management, quality, and maintenance tools are used and where the interaction between the several areas is non-existent.

In this way, the implementation of ISO 55001 will be easier where other management tools have already been implemented and consolidated in the organization.

Table 3 Scoreboard reached

Stage		Surveys	Company Score
1	A.	Understanding the organization and its context	1,8
2	B.	Understanding the needs and expectations of stakeholders	2,2
3	C.	Determining the scope of the asset management system	1,7
4	D.	Asset management system	0,0
5	E.	Leadership and commitment	0,0
6	F.	Policy	0,0
7	G.	Organizational roles, responsibilities and authorities	0,0
8	H.	Actions to address risks and opportunities for the AMS	0,0
9	I.	Asset management objectives	0,0
10	J.	Planning to achieve asset management objectives	0,0
11	K.	Resources	0,0
12	L.	Competence	0,0
13	M.	Awareness	0,0
14	N.	Communication	0,0
15	O.	Information requirements	0,0
16	P.	Documented information	0,0
17	Q.	Operational planning and control	0,0
18	R.	Management of change	0,0
19	S.	Outsourcing	0,0
20	T.	Monitoring, measurement, analysis and evaluation	0,0
21	U.	Internal audit	0,0
22	V.	Management review	0,0
23	W.	Nonconformity and corrective action	0,0
24	X.	Preventive action	0,0
25	Y.	Continual improvement	0,0

Figure 6 illustrates the company's positioning radar map.

It can be said that the entity must improve its management culture in order to implement ISO 55001 and, at this stage, its application is completely inadequate.

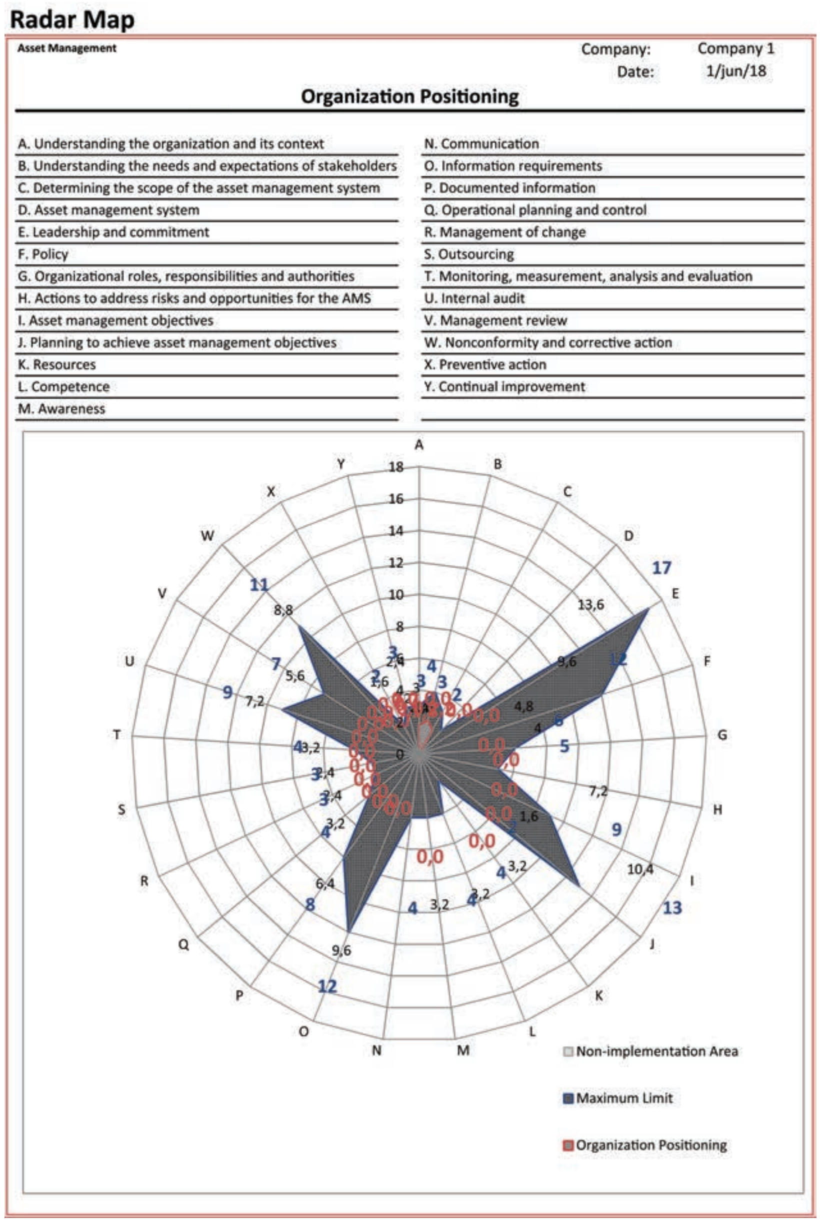


Figure 6 Radar Map.

5 Conclusions

The diagnostic model developed to support the implementation of the ISO 55001 standard is easy to use and provides concrete results to support organizations by identifying their strengths and weaknesses for their implementation, and also provides help to improve though a PDCA (Plan. Do, Check, and Act) cycle.

The final result of the diagnostic model allows an "X-ray" of the entity through a radar map, as well as several supporting reports where results are made visible what it is already, according the standard and what must be implemented or improved to comply with standard.

The model was validated in a public institute and resulted in a diagnosis that coincides with what was predicted empirically in relation to the primary state of the management culture in which it is found, and because the public institute directing board didn't authorize the results to be made public, we needed to hide its identity.

The model, in addition to the initial diagnosis, corresponds to a tool to support the implementation of ISO 55001 and to help the organization make corrections and improvements after its certification.

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