Department of Engineering and Management

Stakeholder Analysis in the Valorization of Plastic Waste Supply Chains

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Abstract — The recurrent use of plastics in a wide variety of markets has led to exponential growth of worldwide plastic production. However, this extraordinary growth has come at the cost of alarming rises in plastic waste levels across the world. Several resources and investment have been deployed to waste management sectors, with plastic waste being particularly targeted across the EU, Portugal included. Despite promising research and technological developments, recycling rates have stagnated as approaches seem to be hampered by the ample number of the system's stakeholders, and the complex nature of their relationships. Waste management now calls for the more integrated approaches that Circular Economy concept provides, targeting all stages of the value chain. Therefore, this research aims to provide a holistic stakeholder analysis of Portuguese plastic waste supply chains, based on the framework developed by Reed et al. (2009). Thus enabling the formulation of best-fit strategies targeting an improved valorization of the system. A state of the art review on Circular Economy (CE) and stakeholder analysis methodologies for the identification, categorization and investigation of inter-stakeholder relationships was carried out, which provided a theoretical basis for conducting semi-structured interviews with key actors of the system and an evaluation of the system's performance. The results of the analysis, which included a stakeholder-led assessment of the remainder in terms of 'Power', 'Interest', and 'Support', and Social Network Analysis, allowed to pair generic stakeholder analysis strategies with efficient CE practices for developing research-supported strategic action plans to address the valorization issue.

Keywords: Plastic, Waste Management, Circular Economy, Stakeholder Analysis, Recycling

1. Introduction

Plastic production has grown exponentially over the last century, driving plastic waste generation to levels that no longer comply with planetary limitations. This has had significant environmental implications and led to numerous waste management initiatives and policy implementation with the aim of containing and reducing the implicit environmental damage (Velis, 2015).

Waste management in Europe and Portugal, particularly, has involved complex and multi-faceted trade-offs among a plethora of technological alternatives, economic instruments and regulatory frameworks (Pires et al, 2011), and no comprises a vast number of stakeholders, characterized by complex relationships. This points to the fact that, in order to significantly address the performance of the system, a previous, holistic analysis of the actors and their relationships, such as the one provided by stakeholder analysis (SA) tools, is deemed necessary.

In addition, Circular Economy (CE) practices have emerged as efficient solutions to boost environmental sustainability of value chains and a major prerequisite for an integrated waste management systems.

Starting by a brief contextualization of Portuguese waste management systems, and reviewing the state of the art on CE activities and SA, this dissertation aims to provide a holistic analysis of the Portuguese plastic waste supply chains for integrating CE practices towards improved valorization.

1.1. Contextualization

Modern waste management can be said to comprise the operational, financial and administrative activities involved in the collection, transport, processing, recycling or disposal, and monitoring of waste material. Demirbas (2011) breaks down the four main parts that should be included in modern waste management systems: i) waste production, ii) collection and transport systems iii) treatment or reprocessing (of waste materials) iv) final disposing. Advanced waste management systems should also include prioritized management strategies to minimize negative environmental impact and preserve resources. The several steps that constitute each part of a waste management system are tabulated in Table 1.

Challenges arise in waste management and the recycling activity specially due to the fact that for each of the activities it compromises, regardless of the waste source

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and destination, it comes at a financial and environmental cost.

Table 1 - General components of waste management systems

Main Parts	*Subparts*
Waste production	Waste sources Source separation Internal collection Production rates Waste types
Collection and Transport	Collection Transport Transfer
Treatment or Reprocessing	Physical reprocessing: Shredding, sorting, compacting Thermal reprocessing: Anaerobic digestion, aerobic composting Biological reprocessing: Anaerobic digestion, aerobic composting
Final Disposing	Recycling Landfilling Energy Recovery

Plastic recycling, particularly, remains consistently limited in Europe, when compared to other recyclable materials. Current global rates for plastic are thought to be around 20%, whilst glass sit over 30% and metals might exceed 50% (Milios et al., 2018).

Plastic waste management in Portugal varies according to capacity (i.e. 'big' or 'small' producers), and to the typology of plastic (i.e. packaging or non-packaging), leading to three major plastic waste supply chains:

i. Plastic Packaging Waste for Small Producers (final consumers or SME's, also known as urban waste);
ii. Plastic Non-Packaging Waste for Small Producers (final consumers or SME's);
iii. Plastic Waste for Big Producers.

In Europe, the packaging sector is accountable for about 40% of total plastic demand, which then are converted into over two thirds of total plastic waste (Velis, 2015). This severe impact of the packaging industry draws particular attention to the importance of having a specific system targeting this waste typology. Still, Portuguese recycling rates for plastic packaging waste (35% in 2017) seem far out of the 50% target for the year of 2020 (APA, 2019).

Given the above mentioned facts, a sense of urgency emerges when addressing the performance of the Portuguese plastic waste supply chains. And the weight of the packaging sector suggests a need for specific strategies targeting this waste stream.

The multiple entities that are involved in the Portuguese plastic waste supply chain, and the complex nature of their relationships, emphasizes the importance of adequate stakeholder analysis when addressing the system. In addition, when addressing improved valorization of the supply chain as whole, CE practices arise as the best-fit integrated solutions for that achievement.

This dissertation, following a state of the art review on the relevant literature, aims to conduct a holistic stakeholder analysis to the Portuguese plastic packaging waste supply chain, for proper integration of CE practices when developing strategic action plans with the aim of improved valorization.

2. State of the Art

2.1. Circular Economy

Looking back to the beginning of the industrial revolution, new manufacturing methods enabled mass production of goods resulting in low cost and high availability products, which then sustained the new consumer societies. This staggering growth of both industrial and human activities consequently led to an also impressive and unprecedented rise in emissions, waste generation and severe landfilling, all coming at the cost of excessive natural resource consumption (Lieder & Rashid, 2016). In the light of the discussed series of challenges, over the last decade, the concept of a CE model has been subject of worldwide growing attention, with the aim of providing a sustainable alternative to the dominant "take, make, use, dispose" economic development model (Lieder & Rashid, 2016). One major problem of this reigning linear model model is pointed out by the Ellen Macarthur Foundation (2012) as being the inherent unnecessary resource losses. And it is possible to group these redundant leaks into four major groups: i) Waste in the production chain; ii) End-of-life waste; iii) Energy Use; iv) Erosion of ecosystem services.

When addressing these leaks, successful implementation of CE depends on the actions and behaviors that are being adopted. There are five main broad activities that definitely need to be followed in all circular economy strategies: i) Eco-design; ii) Green procurement; iii) Cleaner production; iv) Service economy; v) Sustained lifespan; vi) Recovery economy.

Applying these conceptualizations to waste supply chains should require coordinated actions from a wide range of actors and organizations, particularly in this case of the complex Portuguese waste management system. A well-established approach to the management of a system involving several entities is provided by stakeholder analysis.

2.2. Stakeholder Analysis (SA)

The concept of *stakeholder*, initially coined by the Stanford Research Institute in 1963, referred to "those groups without whose support the organization would cease to exist" (Mitchell et al. 1997). The concept was then broadened by Robert Edward Freeman (1984) in his landmark book - *Strategic Management: A Stakeholder*

Approach - to "any group or individual who can affect, or is affected by, the achievement of a corporation's purpose". Even broader definitions were proposed in attempts to translate the empirical reality that virtually anyone can be affected by an organization's actions, as well as narrower definitions, reflecting the damaged effectiveness in managers pursuing to attend all potential claims (Mitchell et al., 1997).

According to Reed et al. (2009), SA can be characterized as a process that: i) Delimitates the scope of the issue being affected; ii) Identifies the individuals, groups and organizations (i.e. stakeholders) who are affected within those delimitations; iii) Categorizes stakeholders for their involvement in the decision-making process; iv) Investigates the multiple interdependent interactions between those stakeholders.

Several methodologies directed at delivering each of the above mentioned steps have already been developed. Regarding stakeholder identification, particular attention is called to the 'snowball sampling' technique as one of the most mentioned throughout the literature, as it takes advantages from different perspectives for deepening the knowledge on neglected entities and further insight on the system's functioning (Hair et al., 2014).

For achieving proper stakeholder categorization, the 'Power vs. Interest' matrix is perhaps the most commonly applied method, and on that can be complemented via 'Support vs. Opposition' grid, for improved perception on who are the actual active mobilizes in the context.

In regard to investigating stakeholder relationships, Social Network Analysis (SNA) "is a research technique that focuses on identifying and comparing the relationships within and between individuals, groups and systems in order to model the real-world interactions at the heart of organizational knowledge and learning processes." (Caniato et al., 2015), and is suggested as an effective approach for understanding relations in stakeholder networks in complex systems (dos Muchangos et al., 2017).

The majority of SA techniques require some type of interviewing to perform tasks such as selecting participants for research, gathering information about stakeholders and the surrounding environment, and using stakeholder participation as analysis input (Wilson, 2013). Concerning interview techniques, it is possible to highlight semi-structured interviews as an effective tool for gathering systematic and in-depth data about a set of topics, while allowing some freedom towards addressing other related issues (Wilson, 2013).

Mingers and Brocklesby (1997) state that the combination of two or more scientific methodologies during the analysis process is likely to produce a richer picture for understanding complex systems and the associated relationships and connections. The following section describes in detail how the mentioned methodologies were combined for the devolvement of this dissertation.

3. METHODOLOGY

3.1. Stakeholder Analysis Multimethodology

The adopted methodology for SA is based on the framework developed by Reed et al. (2009), and the suggestions by Mingers and Brocklesby (1997), as more than one SH tool is adopted during each stage of the analysis procedure. This thesis methodology is comprised by three major phases, each with its adjacent septs. A schematic representation in provided in Figure 1.

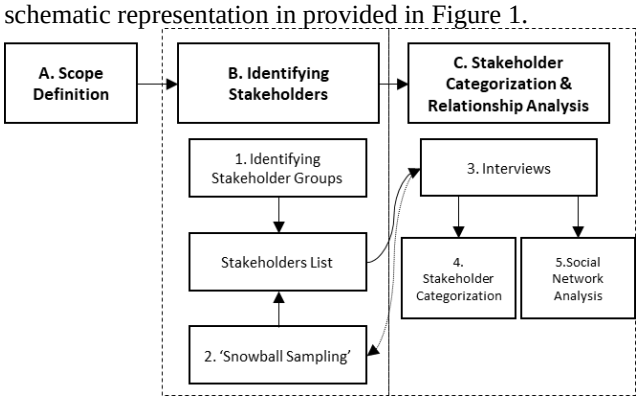

Figure 1 - Dissertation's stakeholder analysis multimethodology

During phase A, the scope of the dissertation was delimited to the urban plastic packaging waste supply chain, due to the relevance of the packaging industry and the complexity of the Portuguese system for addressing this waste stream.

Phase B consists of a literature review on stakeholder analysis in waste management systems, where key generic stakeholder groups are defined and an initial stakeholders' list is developed (1). This list is then expanded by implementing a 'Snowball Sampling' procedure (2) through semi-structured interviews with the identified actors (3). In addition, a complete description of the system's flows and performance was developed through a web research based on official documents, scientific databases and other safe and related-to-topic online sources. The performance topic was also addressed during the semi-structured interviews (3) for non-online expert opinion.

Phase C comprises stakeholder categorization and relationship analysis. Stakeholders will be differentiated through an interviewee-led evaluation according to the following tools (4): 'Power vs. Interest' matrix and the 'Support vs. Opposition' grid, whilst stakeholder relationships will be analyzed through SNA (5). All three mentioned analysis tools are to be based on the stakeholders' own qualitative and quantitative judgements to be obtained through the interviews (3).

As above described, input data for steps 1, 2, 4 and 5 is to be collected via semi-structured interviews (step 3) with several organizations from the identified stakeholders' list. As so, an interview guide was elaborated.

3.2. SWOT Analysis

In order to combine the results from SA and develop strategic action plans that target the supply chain valorization, the quantitative and qualitative results were matched in worksheet for a SWOT analysis (see Table 2).

Table 2 - Worksheet SWOT analysis (adapted from Srivastava et al., 2005)

Factors	*Questions*
Strengths	What are the advantages / benefits? What are the factors supporting the valorization topic? Do the stakeholders show willingness for supporting the program? Are the stakeholders well positioned within the system?
Weaknesses	What could be improved? What is not done properly? What should be avoided? What are the barriers preventing valorization? Where are the complaints coming from?
Opportunities	What are the interesting trends? What benefits may occur from valorization? What changes in governmental policies related to the Portuguese plastic waste supply chain may be possible?
Threats	What are the barriers could valorization face? Are the required support and necessary resources for valorization available? Are there any real weak links in the system?

4. RESULTS

4.1. Stakeholder Identification

After a literature review on stakeholder analysis in waste management systems and contextualization within the current Portuguese plastic waste supply chain, six broad groups of stakeholders were identified and selected for analysis, according to different sectors of intervention: i) Academia, ii) Civil society, iii) Funding/Financial Institutions, iv) Governmental authorities, v) NGOs and vi) Service Operators. These key stakeholders and referencing literature are summarized in Table 3.

In this particular case, it was acknowledged that the 'Service Users' stakeholder group required a higher degree of discrimination. In that sense, the 'Service Users' were divided according to nature of activities, adding five more stakeholder groups: i) Producer Responsibility Organizations (PROs); ii) Packers and importers of packaging products; iii) Urban waste management operators (UWMOs); iv) Other waste management operators (other WMOs); v) Recyclers.

Table 3 - Stakeholders in waste management systems

	Academia	*Civil Society*	*Financial Inst./ Agencies*	*Government/ Gov. Authorities*	*NGOs*	*Service Operators*
Delmas & Toffel (2004)		●		●	●	
Joseph (2006)	●	●		●	●	●
Heidrich et al. (2009)	●	●		●	●	●
Lienert et al. (2013)		●			●	
Wilson et al. (2013)			●	●	●	●
Caniato et al. (2014)	●	●		●	●	●
Xu et al. (2016)	●	●	●	●	●	●
Muchangos et al. (2017)	●	●	●	●		●

Based on this groups, web research on the Portuguese plastic packaging waste supply chain revealed an initial stakeholder list comprising 40 entities/organizations. After the interviews and the application of the 'snowball sampling' procedure, another 9 actors were identified, hence the final stakeholder list totaling 49 entities. From all 49 stakeholders from the disclosed stakeholder list, 32 were invited to participate in the interviews.

Having identified the system's stakeholders, the next step was to understand how stakeholders operate and how does the system function.

4.2. System's Material and Financial Flows

The Portuguese plastic packaging waste supply chain is part of the Integrated System for the Management of Packaging Waste (SIGRE, in the Portuguese acronym), which was created to provide the legal obligation related to the extended producer responsibility policies. It is a collective management system financed by organizations in the packaging value chain. Figure 2 represents a scheme of the system's functioning, the main relationships amongst players and both material and financial flows. Both flows are characterized by numbers and letters, respectively, for facilitated explanation.

The producer responsibility organizations (PRO) work as the central organizations for the collective management of these systems. Until 2016, Sociedade Ponto Verde (SPV) had been the single active Portuguese private and non-profit organization responsible for managing the packaging waste system in Portugal, when Novo Verde acquired their license and became the second operating PRO. In 2018, Electrão also joined and now has a share of the packaging waste business (APA, 2019). Still, in the year of 2018, SPV held a market share of over 85% for overall packaging and 77%

for plastic packaging, making it the most representative of the three organizations (SPV, 2019).

The material flow starts with the raw materials that are used as input for the production of plastic packaging material, which is later sold to the packers and packaging products importers. Both packers and importers have the obligation to submit their packaging waste management to the Portuguese collective system, through one of the three licensed PROs. Once the consumer buys and uses a certain plastic packed product (1), the packaging waste is either selectively disposed through recycling containers – source segregated (2a) – or discarded through undifferentiated disposing methods (2b). The collection of both source segregated and undifferentiated waste is carried out by the UWMOs (*SGRU*, in Portuguese).

After the collection, the waste material is transported to SGRU owned sorting facilities. The source separated plastic waste (2a) is sorted by plastic type, allowing an improved homogeneity and quality of the waste material. Plastic waste can be divide into five types: i) PET (Polyethylene terephthalate); ii) HDPE (High-density polyethylene; iii) EPS (Expanded Polystyrene); iv) Plastic Film; v) Mixed Plastics.

Undifferentiated waste (2b) is subject to mechanical treatment in attempt to recover any recyclable material, including plastics, which then is also sorted by plastic material type (but with a lower quality of both separation and recycled material). Plastic waste that is not eligible for recycling or that was not possible to sort (3b) is sent to landfills or energy recovery. As for the plastic material that qualifies for recycling (3a), PROs are responsible for auctioning it to the recycling companies (referred as Recyclers in the schematic representation). During their production process, recyclers have associated scrap rates, that depend on batch quality a plastic type. The unwanted scraps, have to be transported back to the SGRUs, for disposal via landfill or energy recovery.

Regarding the financial flow, the main input to the system is the 'ecovalue' fee (A), paid by the companies – packers and importers of packaging products – for transferring their responsibility for the recovery and treatment of the packaging waste to the PROs, representing about 80% of the latter's total revenue. The PROs are then responsible for financing all of the system's activities. The majority of the costs – about 90% in the case of SPV – arises from the reimbursements that PROs pay to the SGRUs for the collection, treatment and sorting of packaging waste – 'Counterpart value' (B).

The plastic packaging waste is held by the SGRUs whilst the PROs are responsible for selling it to licensed waste treatment operators – Recyclers. It is sold through a public bid occurring in PRO owned online platforms. The exchange value for the waste derived material can be designated as 'Retake value' (C), and it represents the remainder of PRO revenue. The value for which the material is sold is directly related to the materials market and, depending on prevailing demand and batch quality, it can assume negative values. Meaning PROs pay to the recyclers so they take the plastic waste material.

Finally, Recyclers must pay to the SGRUs for the disposal of the material deriving from their spoilage (D). Choosing SGRUs is usually a matter of proximity, as recyclers must also cover the transportation costs.

Performance wise, according to official data, Portugal shows similar numbers when compared to the EU-28 average regarding packaging waste recycling rates (APA, 2019). After a steady growth stage, in 2009, packaging waste generation took a downturn that lasted until 2012, mainly attributed to the deep impact of the economic crisis in the country. That trend was again reversed, and after another steady growth, in 2017, total packaging waste amounted for 1,709,941 tons (APA, 2019). On the other hand, recycling rates have shown a different pattern, as recycling rates took a significant downturn in the year of 2017. In Figure 3 it is possible to visualize the evolution of Portuguese recycling rates for plastic packaging waste over the past years, as well as the target set for 2020.

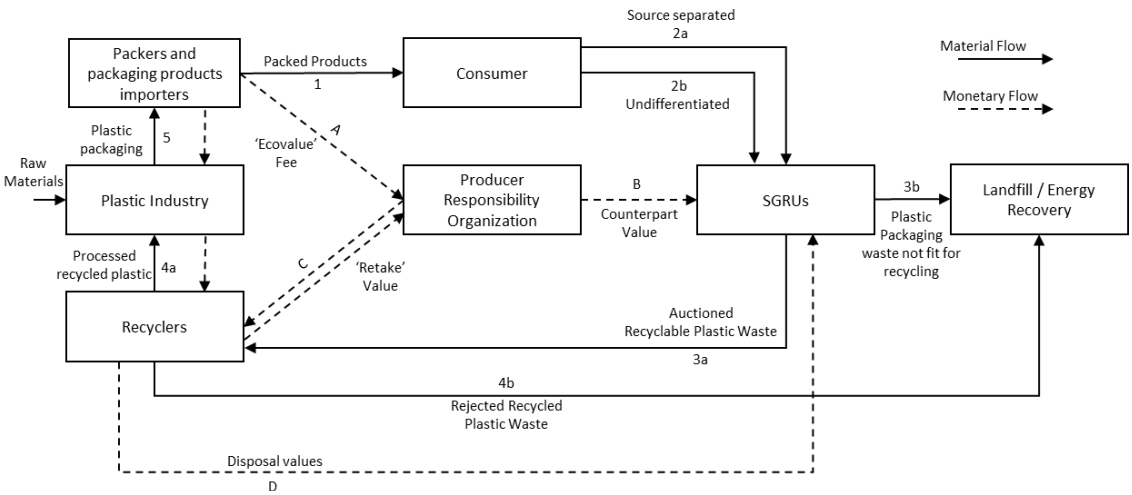

Figure 2 – Portuguese Plastic packaging waste supply chain

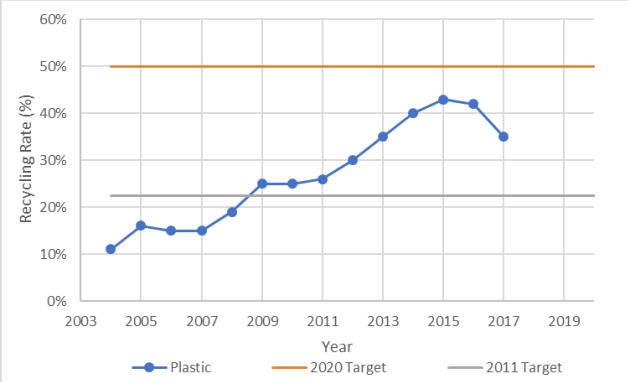

Figure 3 - Portuguese plastic packaging recycling rates and 2020 target (APA, 2019)

Interviewees were confronted with the above mentioned data, and questioned about the system's performance, particularly the reasons behind the downturn in plastic recycling rates. The results from their responses is presented next.

4.3. Interviewees View on System's Performance

While interviewees were subject to several questions on the evaluation of the current system's performance, there were two major subjects which were pointed out as the main drivers behind the decline in recycling rates:

- The introduction of a competitive model for the Portuguese extended producer responsibility scheme for packaging waste in 2017 (year of the major downturn). With the entry of a newly licensed PRO. Later, in 2018, another PRO entered the system, meaning the current Portuguese packaging waste supply chain is now managed by three organizations.
- In April of 2017, the Chinese government approved a ban on imported recyclable solid wastes. The ban included 24 kinds of solid wastes, amongst which non-industrial plastic waste is the most prominent. Prior to this ban, China and other developing countries in East Asia were the destinations of a substantial share of plastic waste exports by higher-income countries, Portugal included.

In regard to the new PRO competitive model, the majority of the interviewees shared a skeptical opinion on its efficiency. There seemed to be three major reasons supporting this position: i) Overall opinion is that the added bureaucracies are hampering the efficiency of a previously well-functioning system. In addition, it was also mentioned that the aimed improvements that would derive from competition are still yet to match the economies of scale associated with a single PRO - "*At the end of each working year, it is necessary to manage the financial compensations between PROs for the discrepancies between allocated shares and the actual amount each PRO managed. This requires both human and financial resources and has associated costs"* – said one interviewee; ii) Competition could be incentivizing lower recycling rates. As already mentioned, the majority of PRO costs derive from the counterpart values they must pay to the SGRUs for the collection of the waste material. As so, in order to reduce costs for coping with the competition, lower collection rates would lead to costs reductions for the PROs; iii) The third reason is that, as one interviewee stated, this model "*(...) actually introduces a fake sense of competition."*. Counterpart values (90% of total PRO revenue) are enforced by the government and standardized for all PROs, meaning "*PROs are only competing for the remainder 10% of the system's costs and for market share of packers and importers of packaging products. Meaning PROs are competing in a highly regulated an standardized market, which can be somehow controversial"*.

On the other hand, after the Chinese import ban, Europe was flooded with plastic waste material that could no longer be recycled via the previous transoceanic solution. Still, data shows that the resulting excessive supply was mainly reflected on the flow of recycled plastic film, the main target for exports, with other flows displaying only slight variations.

In order to promote the valorization of the plastic waste supply chain, other than the flows, it is necessary to understand which stakeholders have the biggest role in this valorization context. Given so, this analysis was complemented by the categorization of the stakeholder groups.

4.4. Stakeholder Categorization

The evaluation and categorization of stakeholder groups was performed considering three main attributes – Power, Interest and Support. The data supporting this evaluation was provided through the interviews when interviewees were asked to evaluate each stakeholder group in regard to the three mentioned attributes, using a score system from 1 to 5 points, where 1 is the lowest score (e.g. very little power/interest and strong opposition) and 5 is the highest (e.g. very strong power/interest and strong support).

After gathering all the scores from the interviewees, the average score of the stakeholder groups in each attribute was calculated. These average scores allowed to implement the two categorization methods that were mentioned in Chapter 2 – 'Power vs. Interest' matrix, and 'Support vs. Opposition' grid – that are represented through Figures 4 and 5, respectively.

The 'Power vs. Interest' matrix is supposed to divide stakeholders into four major categories: i) Players – Who have both high interest and high power, ii) Subjects – Who

have high interest but less power; iii) Context Setters – Who have high power but less immediate interest; iv) Crowd – Which consists of stakeholders with less power and less interest.

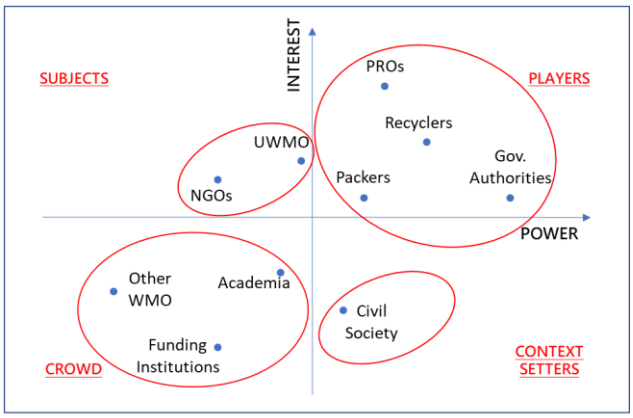

Figure 4 - Power vs. Interest matrix

By matching this categorization results with the remainder of interview information, the following factors were highlighted, in regard to the 'Players' (PROs, Recyclers, Packers and Governmental Authorities):

- Government interest derives not only from the fact that recyclability is globally recognized as a common good, but as they are the main national respondents to EC legislation and directives. Their maximum power comes mainly from the fact that they impose the legislation under most of the system's organizations operate;
- PROs are considerably powerful as they are the central entity that assures the flow of material along the supply chain. Their main interest in the valorization topic seems to derive from expected better financial results and easier material outflow, as they have fines associated with not complying with set out targets.
- Packers hold high interest as they are constantly targeted by national and European directives and the main subjects of packaging legislation. In addition, 'ecovalue' fees not only represent substantial expenditures for this group, as they are the major financial input of the system, suggesting the system's sustainability is highly dependent on the monetary compensation from the packaging industry.
- On the side of the recyclers, power and interest come from the fact that they are the most responsible for expanding the demand for the final recycled material, which is also a major financial motivation. Interviewees also stated that some of this group's power derives from the relatively small number of recycling companies, giving them considerable bargaining power.

As for the 'Subjects' category (UWMOs and NGOs), their source of interest differs considerably in nature. UWMOs were associated with financial motivation, as improved valorization should translate into better compensations. On the other hand, NGOs stakeholders are mainly associated with environmental agencies, so improved waste valorization should is perceived as a common good. UWMOs limited power was attributed to the fact that they are limited by the government standards, operating area, and the disposal culture of the population they cover. While NGOs low power was attributed to lack of numbers and influence across the system.

The 'Context Setters' category is solely represented by the Civil Society, as their behavior was widely referred to as a major limitation towards better valorization of the waste material, which justifies their considerable power. Interviewees highlighted the high margin for improving material quality by simply adjusting consumer behavior and disposal habits. They also highlighted their reluctancy in committing to these adjustments, justifying the low interest.

Finally, the 'Crowd' category (OWMO, Academia and Funding Institutions) was attributed low power and low interest as they are not as actively involved nor concerned as other stakeholder groups. In addition, the representative entities of these groups are still rather small in number and unable to have a significant impact in the system.

After coming fairly close to deciding who the 'key' stakeholders are, the next step was to generate healthy discussion to reveal which stakeholders should be included in the more public beginning of the valorization effort through the 'Support vs. Opposition' grid (see Figure 5).

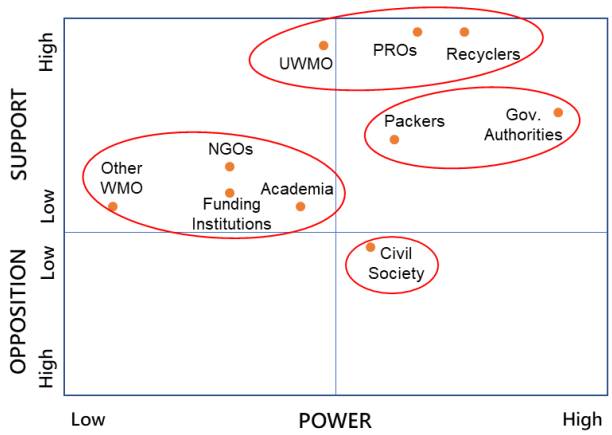

Figure 5 - Support vs. Opposition Grid

From the literature review it is known that this grid is supposed to classify stakeholders according to four major labels: i) Strong Supporters; ii) Weak Supporters; iii) Strong Opponents; iv) Weak Opponents.

Regarding the results from the 'Support vs. Opposition' grid, it is possible to highlight the fact that, with the

exception of civil society, no stakeholders had a perceived opposing attitude in the valorization topic. Which shows a substantially positive picture towards effectively making this transition. For this reason, a slight adaptation was made to the literature with the introduction of a more specific nomenclature. Based on interviewee responses, stakeholders were classified according to the following labels:

- 'Key Supporters' - Comprising the Recyclers, the PROs and the UWMO (SGRUs). This label was added to the original literature and encompasses stakeholders who have the most power and are likely to be the most supportive in terms of actively mobilizing their resources and the remaining stakeholder groups towards a successful supply chain valorization, which means their participation is highly critical.
- 'Strong Supporters' - includes Packers and Governmental Authorities. It is meant to distinguish those stakeholders which have high power but are likely to mobilize reduced resources and show less commitment when compared to their full capabilities, in the sense that they support the valorization topic but it does not pose an immediate priority.
- 'Weak Supporters' - this label comprehends Other WMO, NGOs, Funding / Financial Institutions and Academia, and intends to represent the stakeholders which show minor support or adopt a neutral position, and have little power when compared to other stakeholders. As so, their individual commitment is not likely to produce significant improvements.
- 'Strong (Moderate) Opponents' - solely represented by the civil society. It was adapted from the original literature as civil society's 2.88 average score is considerably close to a neutral position, but still suggests some probability of a reluctant stakeholder group in regard to a valorization effort. The common opinion is that "*Civil Society can, on one hand, be the main promotor of sustainability measures. We are experiencing an increased commitment towards proper recycling by the population, yet there is a vast majority not willing to collaborate. Most people still lack a direct motivation or greater compensation for their effort.*", said one interviewee.

Other than just categorizing stakeholders, a holistic approach to stakeholder analysis requires an in-depth view on how stakeholders interact with each other, for improved management of their relationships. Social network analysis provides insights into patterns of communication, trust, and influence between the actors within a system. For those reasons, during the interviews, interviewees were questioned about the level of information sharing that their stakeholder group had with the remainder, enabling to build a SNA model that was latter analyzed with the use of UCINET software (version 6.685).

4.5. Social Network Analysis

The interactions and degree of information exchange amongst stakeholders that were obtained through the interviews were mapped and are presented in Figure 6.

Each node represents one stakeholder group and information exchange is not homogeneous throughout the network. This feature is illustrated through the line coloring system, as the color of the lines (connections) vary according to how strong the connection in the analysis is. Stakeholder pairs can either have null/scarce information sharing – no connection -, occasional information sharing –

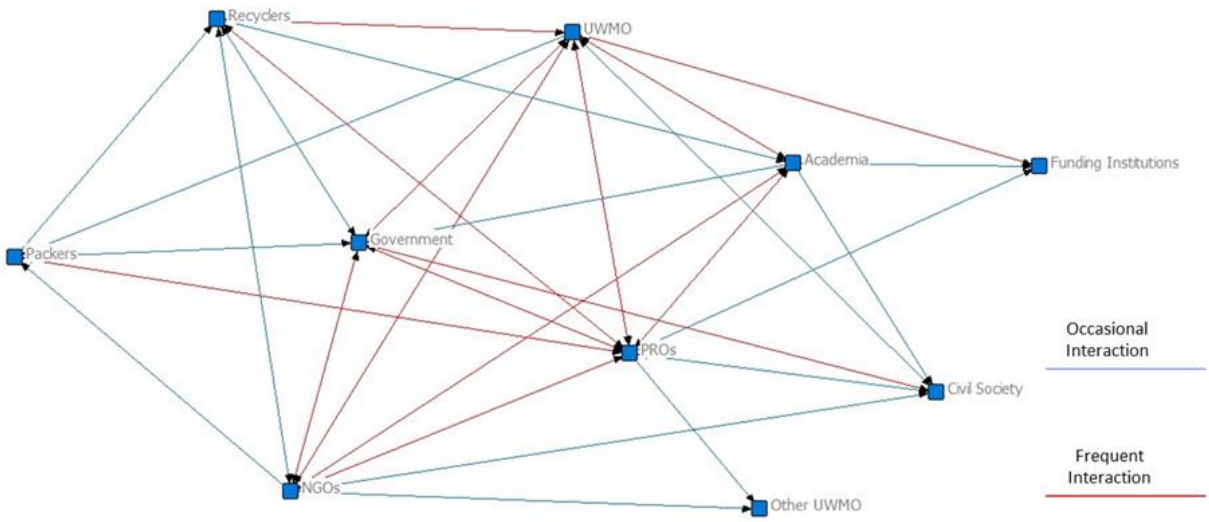

Figure 6 - Social Network Diagram

blue line – or frequent information sharing – which is represented by the red lines.

Overall assessment shows that few stakeholder groups are either disconnected or only partially connected to others. In addition, during the interviews, no respondents stated to be really cut off from information flows. In-depth analysis of this social network was developed by analyzing two major network parameters – Density and Degree of Centrality.

Network density ($D = 0.42$) describes the portion of the actual connections in relation to all potential connections in the network, providing a degree of overall connectiveness of the system. Scores closer to zero, such as the resultant from the mapped network, point towards a certain level of overall disconnection. This disconnection can be better distinguished in the results for the actor degree centrality that are presented in Table 4. When matching these results with the literature from SNA, overall analysis points out three. important factors.

The first factor, is the fact the majority of strong ties occur between the main high power stakeholders might reflect a considerably centralized network. Although centralized networks are helpful for initial stages of building support for collective action, research suggests that centralized networks are also a disadvantage for long-term planning and problem solving (Olson et. al., 2004). Long-term goals, in fact, require more decentralized structures, with more ties between all stakeholders

Table 4 - Degree of Centrality results

	Out-degree	**In-degree**	**Normalized Out-degree**	**Normalized In-degree**	**Overall degree**
PROs	17.0	15.0	0.94	0.83	0.89
UWMO	15.0	12.0	0.83	0.67	0.75
Gov. Authorities	13.0	11.0	0.72	0.61	0.67
NGOs	14.0	8.0	0.78	0.44	0.61
Academia	9.0	9.0	0.50	0.50	0.50
Recyclers	8.0	8.0	0.44	0.44	0.44
Packers	5.0	7.0	0.28	0.39	0.33
Civil Society	3.0	8.0	0.17	0.44	0.31
Funding Institutions	-	4.0	0.00	0.22	0.11
Other UWMO	-	2.0	0.00	0.11	0.06

The second factor, is the fact that PROs had the best overall score and are the most directly involved in the management of plastic waste material, might enable efficient information and resource sharing for adequate mobilization of the entire system towards improved valorization.

Finally, in contrast, diverse information and new ideas have been shown to travel best through weak ties (Reed et al., 2009). In this particular valorization topic, the intermediate results for the NGOs, Academia and Recyclers, could actually be an advantage when effectively transmitting new technological developments and promoting new partnerships. Nonetheless, the potential drawback to weak ties is that they are easier to break.

In order to better systematize the results from sections 4.1. to 4.5., it was decided to conduct a SWOT analysis of all highlighted factors, by matching these results with the worksheet from Table 2. After properly aggregating the results as ‘Strengths’, ‘Weaknesses’, ‘Opportunities’ and ‘Threats’, it became possible to combine the generic SA strategies for managing stakeholders with CE benchmark practices for an effective valorization of the plastic waste supply chain.

4.6. Developing Strategy Directions

Based on the SWOT analysis, the CE practices that were perceived to target an improved valorization of the system were: i) Eco-design; ii) Green Procurement; iii) Recovery Economy. A summary of how this CE practices would tackle stakeholder groups, and successfully lead to improved valorization is provided next.

Regarding Eco-design, there are already some policies being implemented within the Portuguese waste management system. One clear example is the discount fees applied to packaging that complies with certain measures regarding the recyclability of the material. Still, eco-design policies could be extended and articulated between recyclers and packers to improve this recyclability. The fact that these two stakeholder groups do not share strong ties, means PROs could be an effective mobilizer of this partnership. The associated advantages should be reduced scrap rates for the recyclers, improved material quality, ultimately resulting in extended applications for the recycled material and better overall valorization.

In regard to Green Procurement, there should be active promotion within the whole system for the adoption of measures which improve their environmental sustainability. Green procurement should be particularly promoted within civil society, encouraging the use of recycling prone packaging and products made out of recycled materials.

Recovery Economy could be the most important CE concept to be applicated to the Portuguese plastic packaging waste supply chain. One major practice to be implemented in relation to this concept would be the establishment of partnerships within the recovery system. The system still seems to move upon individual ambitions, with little regard

to overall performance. Other major aspect is to increase cross-sharing within the same stakeholder group. If PRO competition is considered to damage the system's performance, other collaborative alternatives should be considered. This is also applicable to recyclers, as there are already some recycling companies that engage in direct exchanges of unwanted scraps from the waste batches they acquire, but that can still be recycled by other recycling companies. Still, this could be performed in a larger scale and with specific tools, that could be associated to the already existing PRO auction platforms, for example. The final practice associated with this CE activity would be to encourage better product recovery. Although reverse vending systems are already pending implementation, which will allow considerable quality improvements in some types of waste material , interviewees highlighted that these systems would only be applicable to some packaging types. In case of plastic waste, the main target would be the PET bottles. Given so, strategies should be developed to encourage the recovery of the remainder plastic types in order to boost consumer's responsibility and commitment towards proper return of products to the recovery process and superior material quality.

5. CONCLUSION AND FUTURE WORK

This work aimed at providing complete and integrated analysis of plastic waste supply chains, in order to properly address a better valorization of the system as whole.

Supported by a literature review, the implemented stakeholder categorization methods pointed towards an overall positive picture, with most of the system's 'Players' showing high levels of perceived support. This positive picture was overruled by SNA, as the poor results for network density pointed to a significantly disconnected system.

The major conclusion from interview results, is the shared opinion that there is substantial margin for improving plastic waste quality through actions across the several stages of the supply chain. CE has proved to provide the benchmark solutions for addressing this sustainability issues across the entire value chain, and it is believed that SWOT analysis provided a solid framework for adjusting CE practices to the problems to be addressed.

In sum, it is possible to state that this dissertation managed to effectively provide integrated strategic plans, targeting an overall improved valorization of the Portuguese plastic waste supply chain. Future work on the topic should include addressing the major limitations of this dissertation, such as a relatively small interviewee sample. Particular problems that were drawn, such as negative opinion regarding a PRO competitive model, should also be target of a more complete and directed investigation.

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