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Decentralized Composting Analysis Model—The Qualitative Analysis Path

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Abstract: The organic fraction of municipal solid waste (OFMSW) is a significant environmental threat, and an economic and social challenge to manage. As such, the efficient treatment of OFMSW is a significant key factor in achieving sustainable waste management. Decentralized composting (DC) offers a new framework of waste management. The DC analysis model (DCAM) proposed in our previous study provides a powerful tool for decision makers, based on the quantification of the DC project characteristics. In this paper, we focus on qualitative analysis as a complementary tool to support decision making in cases where the quantitative analysis is equivocal. The qualitative analysis identifies the main players in the field, the critical stakeholders, and the potential conflicts between them. It also reveals the root problems and the core competencies for the project's implementation. The DCAM qualitative analysis in the Shefa-Amr case study indicates that unresolved root problems, such as "lack of national regulation", "clear ownership of the project", and "lack of ongoing budget" can result in an unsustainable composting system. Countering that, "commitment of the municipality" together with "economic viability" and securing "suitable areas for placing composters" are among the most important core competencies for the effective implementation of DC projects.

Keywords: compost; decentralized composting analysis model; qualitative analysis; municipal solid waste; organic waste management

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1. Introduction

Increasing attention has been given in recent years to strategies for the effective management of the organic portion or fraction of municipal solid waste (OFMSW), especially within the context of climate change and bio-economy [1]. Managing the OFMSW through composting or anaerobic digestion (AD) can help in the mitigation of and the adaptation to effects of climate change while reducing the free release of methane gas, a greenhouse gas (GHG) in landfills [2,3]. Bio-economy, entailing the production of energy and fertilizers from bio-resources, is also strongly interrelated with the treatment of organic and biodegradable waste. Bio-economy and the reduction of GHG demonstrate the importance of implementing holistic organic waste management strategies and solutions [4,5].

Since OFMSW is mainly characterized by its high moisture and protein content, it can emit noxious odors [6] and may cause insect and rodent problems. In addition, the availability of properly separated OFMSW at source is not always guaranteed, which is reflected in additional collection and transportation costs. Thus, OFMSW has a significant negative environmental impact, as well as high economic and social costs.

Many places around the world are investing a lot of effort to manage OFMSW efficiently, inter alia establishing policies to ban OFMSW landfilling, and to motivate OFMSW recovery using different technologies [7–9].

Over the last few decades, composting has been the most common method of treating OFMSW [10–13]. Composting can be carried out either via a centralized system or a decentralized system, each with its own characteristics and specifications. Centralized composting (CC) is usually carried out using the "windrow" technique, while decentralized composting (DC) involves "in-vessel" composters [14].

Our research deals with DC and aims to provide tools for analyzing the feasibility and viability of DC projects, with a focus on the qualitative analysis path. In our aforementioned previous publication [15], we presented the decentralized composting analysis model (DCAM), focusing on the quantitative analysis path. By providing guidelines and a methodological framework to quantify economic, social, operational, environmental, and regulatory aspects, we were able to quantitatively examine the viability and feasibility of decentralized composting projects at any given location.

The qualitative analysis presented in this paper provides a complementary waste managing approach for implementing DC projects in cases where quantitative analysis is equivocal. It provides an insight into and understanding of the various players and stakeholders, and their respective impacts on DC projects. It also provides an understanding of the interrelationships between regulation and the various stakeholders in the organic waste recycling market. This innovative integrative approach is vital for closing the OFMSW loop and achieving sustainable treatment processes for this organic fraction.

The qualitative analysis path of the DCAM also helps to identify and understand root problems and core competencies for formulating strategies and action plans to remove barriers and promote DC projects effectively. Thus, it is a powerful tool for decision makers to pre-evaluate DC projects, especially when the quantitative feasibility is not clear [16]. It also enables future replicability and transferability of successful DC projects. However, it is important to note that the planning process of composting systems can be challenging, especially when data availability is limited, or the data themselves are uncertain, incomplete, or imprecise, and can be only roughly estimated [17].

In this paper, we describe the qualitative analysis path of the DCAM model and its methodological framework and approaches, in order to form an effective tool for formulating waste management strategies and action plans to demonstrate their implementation.

2. Methodology

There are cases where the quantitative analysis is inconclusive, or when certain aspects of the project are not easy to quantify, in other words, where the quantitative feasibility or viability of the project is not clear or guaranteed. In such cases, qualitative analysis is meant to complement quantitative analysis for supporting decision making.

The qualitative analysis presented in this study combines approaches and methods drawn from the business administration discipline, to form an effective tool for formulating waste management strategies and action plans.

The DCAM framework is shown in Figure 1, in schematic form, and includes both the quantitative and qualitative paths. In this paper, we focus on the latter.

The qualitative analysis path for the DCAM consists of seven steps, as follows:

1. ARENA analysis, based on the focused ARENA strategy [18,19];
2. Constraint analysis, as per the theory of constraints [20];
3. Conflict analysis according to the theory of constraints [20];
4. Strengths, weaknesses, opportunities, and threats (SWOT) analysis;
5. Focused current reality tree (fCRT), relying on value-focused management [18,19].
6. Current competencies tree (CCT), based on value-focused management [21];
7. Implementation roadmap [20]

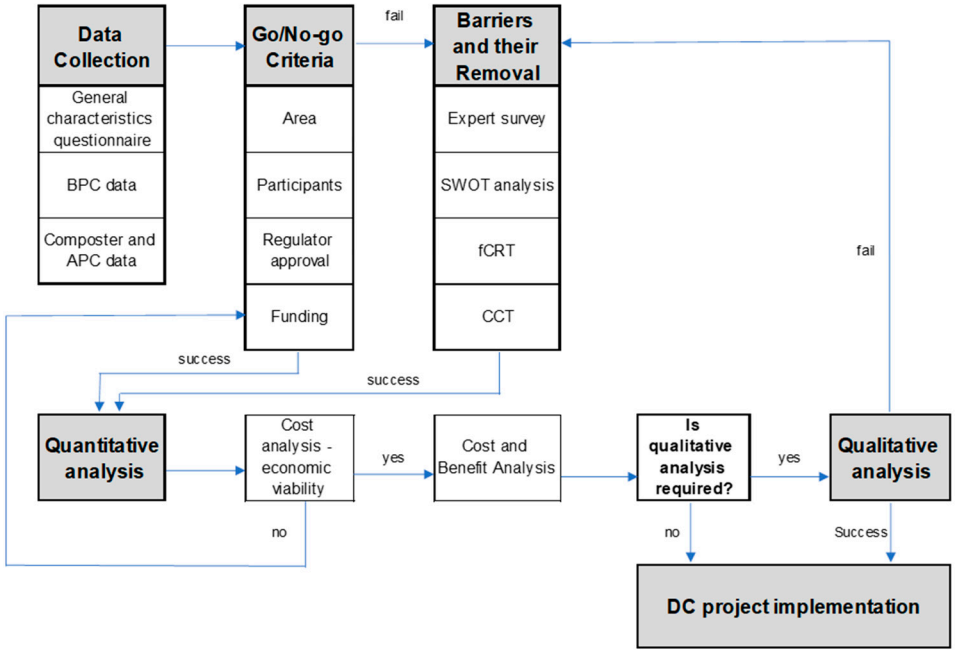

Figure 1. Schematic description of the DCAM framework. Source: [15].

The DCAM qualitative analysis path is schematically depicted in Figure 2.

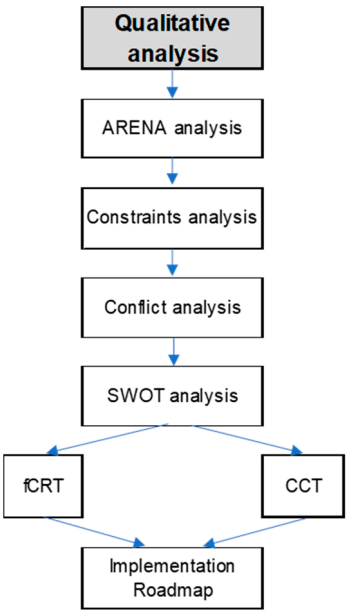

Figure 2. Schematic description of the DCAM's qualitative analysis path. Source: [15].

2.1. ARENA Analysis

ARENA analysis, based on the focused ARENA strategy, is a tool for the mapping and analysis of the environments of businesses, and can be used to map markets and industry sectors. It includes identifying, locating, and mapping the different external stakeholders and players in the arena of the entity under consideration [18,19].

The ARENA analysis consists of the following three steps:

1. Map the main stakeholders including key persons who affect and are affected by the system. To achieve this mapping, a comprehensive survey should be carried out to collect data and documentation, such as laws, tenders, and contracts of both govern-

ment and local authorities, including approved contractors and financial reports, and so on;
2. Map the main players related to the composting system, including project planning and implementation, according to their roles in the different stages of the project;
3. Connect the interrelationships and hierarchies between the various stakeholders and players, including relevancy level, significance, and impact on the project. The relevancy level can be classified in relation to national, regional, or local factors. For DC, we focused on the regional and local players. The significance and effectiveness can be graded based on the differing influences and impacts the players have on composting projects, and particularly DC projects. It should be noted that, although some stakeholders may be very important to the project, their involvement and engagement are not guaranteed, so their ability to influence is very limited.

2.2. Constraint Analysis

According to Goldratt (1990) [22], a constraint is defined as a factor that limits a system, preventing it from achieving its goal(s). A clearly defined goal is, therefore, essential to identifying the most relevant and critical constraints.

Goldratt (1990) categorizes constraints into four types [22]:

1. Resource constraint (bottleneck)—a resource that limits the overall system.
2. Market constraint—a market demand that is lower than the system's output capacity.
3. Policy failure constraint—any policy that limits the system.
4. Idle constraint—a situation where one resource, possibly a very cheap one, by being idle, becomes the bottleneck of the entire system.

In the process of analyzing the constraints, we classified them using the abovementioned categories, then determined how these constraints could be removed.

2.3. Conflict Analysis

After performing the ARENA and constraint analyses, the next step is the identification of potential conflicts between the main or leading stakeholders or players in DC (according to the ARENA analysis), especially players who influence or are influenced by the constraints.

The conflict analysis depends on the composting system type. Conflicts in home composting (the most common practice [23,24]) differ from conflicts in community or in commercial composting.

The most discussed conflicts in the literature for the various types of composting systems are [25–29]:

1. Site selection for DC systems;
2. NIMBY (not in my backyard);
3. Minimal participation rate;
4. Requirements for input material, and rejection of input material;
5. Willingness to pay for the compost;
6. Compost quality guidelines.

The issue of site selection for DC systems is one of the most critical. The composting site should fulfil certain requirements and criteria in order to minimize potential conflicts. It should be accessible, be located near water and energy infrastructures, and include a "sufficient" buffer zone, which can help in cases of malfunction or dysfunction of the composting system [25–29].

The NIMBY phenomenon, or "not in my backyard", is another significant conflict regarding site selection. This relates to local objections to the placement of a facility that is seen as "undesirable" in the local (backyard) vicinity [30,31].

Conflicts between potential participants and either the local authorities or the compost site operators can influence the participation rate. The more people who get involved, the more food waste gets processed. Participation rates also depend on convenience, location,

and even personal resources. So, involvement can vary across a city, with some areas lagging behind others due to factors like distance or income level [32].

2.4. Strengths, Weaknesses, Opportunities, Threats

Strengths, weaknesses, opportunities, and threats analysis, SWOT for short, originates in the business administration discipline. That said, it is widely used in other disciplines, being an efficient analysis tool that can visually display and effectively communicate results [21,33–35].

SWOT analysis identifies and assesses the strengths, weaknesses, opportunities, and threats in a given project's internal and external environments [15,17,30,32,33]. This methodology helps to analyze and evaluate projects, and to assist in strategic decision making [19,21,34,36,37]. The SWOT analysis in the current research consisted of twenty-three interviews with stakeholders, using the general guided approach to collect information, especially at the local and regional levels (see Supplementary Materials).

2.5. Focused Current Reality Tree (fCRT)

The focused current reality tree (fCRT) is a thinking process within the theory of constraints. It provides a snapshot of the current reality, in particular the root causes that lead to most of the undesirable effects and prevent achieving the desired and defined goals and objectives [34]. The fCRT is formed by making logical (causal) connections between the undesirable phenomena (the weaknesses and threats from the SWOT analysis), leading to the "goal is not achieved" outcome. One to four strategic root problems that would prevent the achievement of that goal may be identified in this process [36].

2.6. Core Competence Tree

The core competence tree (CCT) is a methodology to identify the core competencies needed for achieving desired and defined goals and objectives. The CCT is formed by making logical connections between the desirable phenomena and effects [38], i.e., the strengths and opportunities from the SWOT analysis, that always lead to achieving the desired and defined goal. Making these connections can reveal one to four strategic core (root) competencies. As the activity must be strategically subordinated [36] to these competencies, they are the key strategic capabilities to be strengthened.

2.7. Implementation Roadmap

The last step in the DCAM qualitative analysis path is to develop a formal implementation plan that provides answers to overcome the root causes and identifies the root competencies to strengthen, in order to reach the required change. The implementation plan, with stakeholders' input and help, is basically a sequential roadmap, using all the inputs from previous steps, and shows the sequence and responsibilities for implementing the major interventions [20]. The conclusions in this article can be used as the guideline for preparing such an implementation plan.

3. Results

Shefa-Amr (Shefar'am) is an Arab city in the northern district of Israel, located at the entrance to the Galilee region. In 2020, Shefa-Amr had a population of about 43 thousand residents [39]. Approximately 32,000 tons of waste are produced in Shefa-Amr each year, of which 18,000 tons are classified as mixed household waste, according to municipal records. This includes the waste collected from businesses located in the heart of the city and the residential neighbourhoods.

The following are the results of the DC analysis for the city of Shefa-Amr, using the DCAM that was implemented as part of the project 'Decentralised Composting in Small Towns' (DECOST) [40].

Three DC options were analyzed and compared to determine the most viable option for Shefa-Amr, these being commercial composting, community composting, and home

composting. According to the DECOST pilot plans [40], we classified commercial composters as treating 6–14 tons per site per month, while community composters treat up to 1 ton of organic waste per site per month.

3.1. ARENA Analysis

In CC systems, there is usually one dominant planning player (the local authority) and one dominant operating player (the contractor who collects and disposes of the waste). In contrast, in DC projects, there are various players with different impacts at different stages of planning and operating the project. Table 1 presents the typical leading players according to the stages of the DC project.

Table 1. Leading players according to the ARENA analysis for DC.

#	Stage	Leading Players
1	Financial support	EU, UN, Ministry of Environmental Protection.
2	Data provision	Central Bureau of Statistics, local authorities, environmental NGOs.
3	Consulting services and research	Local research centers, universities, consulting firms.
4	Regulatory approval	Planning bodies, Ministry of Environmental Protection.
5	Raising awareness	Local authorities, NGOs (youth, women, and retirees).
6	Organic waste reduction	Food rescue associations, animal keepers, zoos.
7	Waste management	Waste collection contractors, local authorities, local waste transfer stations.
8	Composting infrastructure	Composting companies, local composting facilities, compost equipment suppliers.
9	Organic waste supply (commercial composting)	Greengrocers, supermarkets, restaurants.
10	Organic waste supply (home and community composting)	Schools (certified as eco-friendly or green), households or neighborhoods with active gardens.
11	Marketing	Plant nurseries, farmers' associations.

The critical players in the initial stages (1–5) of any DC project are the supporting bodies (like the EU, UN, Ministry of Environmental Protection) and the municipality, with its related ability to allocate budgets and manage the project.

Other important players include companies that already operate composting systems, like electro-mechanical composters, organizations that work on food waste prevention, and urban gardeners with an interest in organic farming and composting.

Local waste transfer stations and "organic waste generators" like greengrocers are the most important players for community composting projects on a local scale in Shefa-Amr, especially for commercial community composting.

3.2. Constraints Analysis

The constraints analysis for DC projects includes three alternatives which are based on the three different composting options. In Table 2, four main constraints are listed for each type of DC option, namely, resources, market, policy, and data.

Table 2. Potential constraints for different composting alternatives in Shefa-Amr.

Constraint	Constraints for Different Composting Alternatives		
	Home Composting	**Community Composting**	**Commercial Community Composting** *
Resources	Lack of time for composting activities (e.g., composting maintenance).	Lack of facilities for the treatment of waste at suitable distances; identifying suitable locations; allocating budget for operation and maintenance.	Lack of facilities for the treatment of waste at suitable distance; identifying suitable locations; allocating budgets for operation and maintenance.
Market	Very low compost prices in the local plant nurseries.	No community gardens; potential issues related to composting from waste (bad odors, pests, contamination)	Demand for facility end products; low compost quality; potential issues related to composting from waste (bad odors, pests, contamination).
Policy failure	Lack of public cooperation and participation; low participation rates.	Low participation rate; lack of separation at source; lack of clear guidelines for community composting centers.	No cooperation between the central and local government levels; lack of a regulatory framework; access to land and limited space; lack of public cooperation; emphasis on centralized solid waste planning.
Bottlenecks (data and resourses)	Personnel resources; equipment; support systems,	Limited data about food waste flow; lack of technical support in operating and building community composting facilities.	Marginal resources; limited data about food waste flow; lack of technical support for the operation and construction of commercial composting facilities.

* Commercial community composting information is based mainly on organic waste generated in commercial activities.

3.3. Conflict Analysis

The conflict analysis involved identifying potential conflicts for each of the three composting solutions. In Tables 3–5, one for each solution, we describe these potential conflicts, and whom they involve.

HOME COMPOSTING

Table 3. Potential conflicts in home composting.

Side 1	**Side 2**	**Conflict**
Households with home composting	Neighbors	Odor problems and attracting insects and/or mice
Local authority	Residential waste generator	Existence of required conditions for proper operation
Local authority	Residential waste generator	Minimal participation rate to ensure economic viability

Poorly operated composters can cause odor problems and attract insects and/or mice, which is the first conflict. To keep such composters in continued operation will depend on the degree of patience by the neighbours towards such "faults".

The second conflict in home composting is related to the local authority, as it must ensure the existence of required conditions, such as sufficient space to carry out the composting (for instance, over 25 square meters of garden space).

It should be noted that the percentage of participation in home composting projects is typically not high, generally below 20% [32]. A low participation rate will reduce the economic viability of the project and can result in financial losses for the municipality. A high participation rate means that it will be easier to reach the minimum amount of composted organic matter required for the municipality to justify the investment in the home composting project.

RESIDENTIAL COMMUNITY COMPOSTING

Table 4. Potential conflicts in residential community composting.

Side 1	Side 2	Conflict
Waste generator	Local authority	Environmental and/or visual nuisance
Local authority	Contractor or operating body	Ineffective operation and maintenance
Contractor or operating body	Residents	Requirements for input material and potential rejection of input material

The first conflict in community composting is environmental and/or visual nuisance. Residents expect the local authority to manage the composting process in the best way possible, so that the composting systems do not become environmental and/or visual nuisances. Not meeting this expectation will lead to friction, conflict, and possibly to the failure of the entire process (especially owing to bad odor issues). This conflict can play a major role in local authorities where the waste management services are already poor, exacerbating the situation.

The second conflict in community composting is the ineffective operation and maintenance of the systems, stemming from the contractors' tendency to perform the work in the most economical and efficient way for them. This may cause the contractors to operate and/or handle a maximum number of composters in each visit, resulting in a higher possibility of malfunctions.

Even when the composters are operated by volunteers and/or environmental activists, there may still be operational malfunctions, especially when volunteers are unable to invest the time required to perform the work, or when the responsibility for operating and maintaining the composter switches rapidly between volunteers.

The third conflict refers to the requirements for the input material. If residents participating in "waste separation" do not adhere to the organic waste separation guidelines, the likelihood of a lower-quality compost increases. Furthermore, compost operators and/or contractors may refuse the input material if it is not properly separated.

COMMERCIAL COMMUNITY COMPOSTING

Table 5. Potential conflicts in commercial community composting.

Side 1	Side 2	Conflict
Waste generators or business owners	Local authority	Frequency of organic waste removal
Waste generators or business owners	Local authority	Rate of business owners' participation
Contractor or operator	Waste generators or business owners	Organic waste separation guidelines
Residents and neighbors of the Business	Local authority	NIMBY (not in my backyard)
Planning bodies	Local authority	Lack of experience with planning permissions for composting machines/composting plants in mixed use development areas
Local authority	Waste generators or business owners	Non-compliance with organic waste separation guidelines
Ministry of Environmental Protection	Local authority	Approval by the ministry of local composting plants
Ministry of Environmental Protection	Operators of composting sites	Poor operating conditions
Operators of composting sites	Compost costumers	Low quality of compost
Operators of composting sites	Ministry of Agriculture, review bodies	Cost of the continuous analysis of compost quality
Operators of composting sites	Local authority	Availability of an ongoing and continuous budget for the operation

The first conflict in commercial community composting is the frequency of organic waste removal or collection. This is particularly important during weekends, shopping seasons, and holidays, and even critical during the hot summer months, in order to prevent bad odors. According to the initial survey conducted in Shefa-Amr, organic waste generated by greengrocers must sometimes be removed twice or more per day, which increases the transportation costs to a level that the local authority may not be able to afford. From the experience of local authorities with plastic and carton recycling, high transportation costs often lead to the failure of the system. Another related issue is the absence of bylaws, for example an "excess waste bylaw", to make major waste generators pay for their increased waste in order to cover the additional costs of waste management.

The second conflict in commercial community composting is the rate of business owners' participation. When participation is not "mandatory" nor based on well-planned regulations and bylaws, the participation rate is not guaranteed. Low participation rates can lead (in some cases) to high waste-management costs. For example, when the composter is planned for 1 ton per day, and the collected waste is actually 0.5 ton per day, the cost per ton doubles.

The third conflict relates to the organic waste separation guidelines, where non-compliance of "waste generators" with these guidelines will very likely reduce the compost quality.

Another conflict is NIMBY, which refers to the residents' opposition to the proposed composting facilities in their local areas, practically in their own "backyards".

The lack of local experience is also listed as a potential conflict because decentralized composting systems are not common in the Shefa-Amr area, so planning bodies do not have much experience with or knowledge about community composting plants, and this may affect the approval of the project.

Another conflict is obtaining the approval of the Ministry of Environmental Protection before setting up and operating a local composting plant. The local authority must work according to the guidelines of the Ministry, such as maximum capacity, otherwise the Ministry may not approve the plant or may even close it at a later stage following approval.

An additional and important conflict is the poor operation of the composting facility that can result in its closure.

The conflict analysis also indicates that the quality of the compost is a conflict. Low-quality compost will not be purchased, thus the compost itself, ironically, will end up in landfill. Furthermore, there is a need for the continuous analysis of the compost to monitor its quality according to specific guidelines that are not always achievable when composting organic waste. The result is that the costs of the continuous analysis and monitoring are considered a potential conflict for the operators of composting sites.

It is also important to note that conflicts can occur between the local authority and the compost facility operator, especially when the needed ongoing budget is not available, and/or the procedures (quality of input materials) are not clear or well regulated.

3.4. Strengths, Weaknesses, Opportunities, Threats

In this study, we have identified the strengths, weaknesses, opportunities, and threats for a proposed decentralized composting project in Shefa-Amr. These are listed in Table 6, below, along with the social, operational, environmental, and regulatory components for each category.

Table 6. SWOT results for a DC project (Shefa-Amr), including home, community, and commercial composting.

Strengths	Social	The existence of environmental education and/or awareness programs
	Operational	Willingness to separate organic waste, as some households in Shefa-Amr do already separate the bread leftovers, and some green groceries separate part of the organic waste for animal feed
	Environmental	Readiness for self-hauling, with some "big" green grocers already transporting their waste to the local waste transfer station
	Regulatory	Availability of a transfer station in the city; A new waste transfer and recycling station is in the planning stage.
Weaknesses	Social	Low participation percentage (expected); Not in my backyard (NIMBY).
	Operational	Treatment capacity limitation; The need for high-frequency removal of organic waste (additional transportation cost); Insufficient infrastructure for waste separation (bio-waste bins); No adequate infrastructure for treating separated waste, especially dry waste (recycling plants or machines).
	Environmental	The authority is not well prepared for the management of complex waste systems, including separation of waste at source (the current waste management services are poor)
	Regulatory	No bylaws for excess waste (for businesses); Distributive injustice in waste treatment (lack of differential regulations); No "realistic" targets for recycling or reducing food waste; No detailed data exist about the current situation; No regulations or procedures for compost planning, such as bylaws for additional commercial waste; Waste management by a single contractor (monopoly); No mechanism to encourage composting.
Opportunities	Social	On-site environmental education and awareness, e.g., support and growth in the environmental education system; Potential for new jobs (master composter operators).
	Operational	Reducing operating costs in the main waste stream owing to the reduction in organic waste (if no additional transportation costs)
	Environmental	Local compost production; Encouraging local agriculture or farming; Encouraging urban agriculture (community gardens); Improving health and soil quality as a function of compost quality.
	Regulatory	Standards for "green" jobs, such as master composter operators; Low (current) recycling percentage (also a strength) will encourage the municipality to take action.
Threats	Social	No hotline for recycling and composting advice, resulting in poor communication with the operators and local authorities, and "distrust" issues; Lack of effective education and information about composting; Weak enforcement; Extremely low participation rates; Low readiness for the operation and maintenance of the composter over time.
	Operational	Odor and rodent hazards; Collection costs (following increased collection rounds); Need for routine maintenance and the related high costs.
	Environmental	Poor compost quality.
	Regulatory	Non-application of bylaws.

3.5. Focused Current Reality Tree

The process of identifying root problems based on the weaknesses and threats in the SWOT analysis for DC projects is shown in Figure 3. The resulting diagram is called a "fCRT". During the process, three root problems were identified.

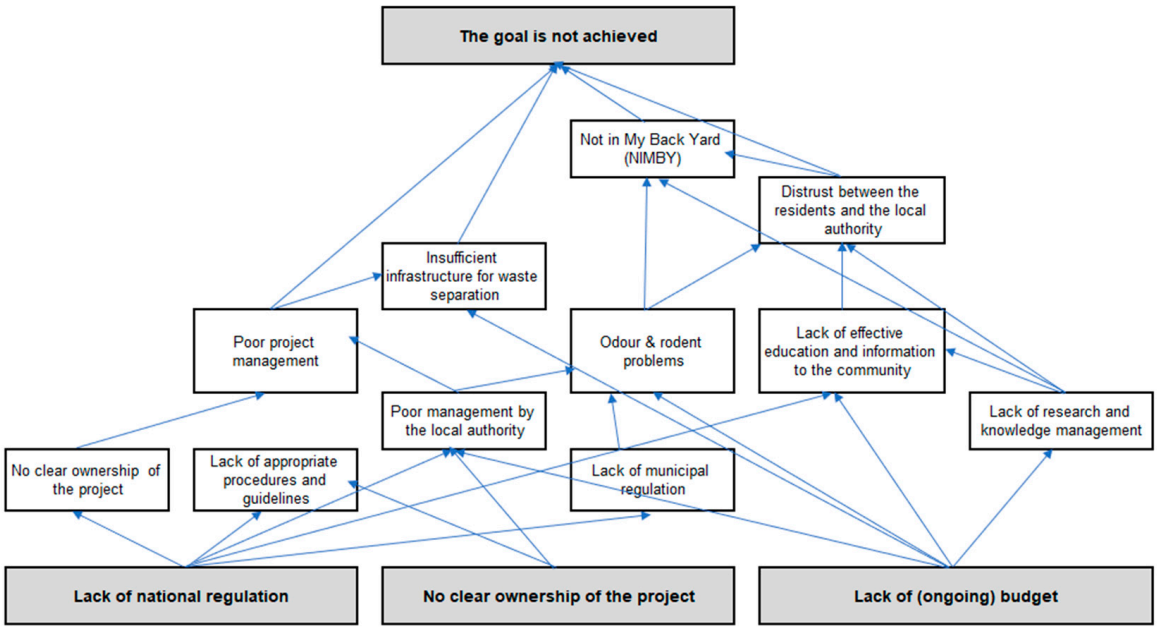

Figure 3. Focused current reality tree for identifying root problems in the implementation of a DC project in Shefa-Amr.

According to this fCRT, the existence of sufficient national regulations for DC and the clear ownership of the project by a professional team together with the availability of an ongoing budget are all critical for achieving the goals. Without them, or even one of them, there could be undesirable consequences.

Three root problems were identified from this process, as follows.

3.5.1. Lack of National Regulations

Based on our study, there are no specific regulations regarding composting in most municipalities in Israel; therefore, it is problematic to plan for community composting or even home composting. Other countries have developed regulations intended to assist in planning and operating composting systems, and, in some cases, improving the economic viability of the project through forcing businesses to pay for their organic waste recycling processes [15].

3.5.2. No Clear Ownership of the Project

To ensure clear guidelines and the proper management of the project, it should be under the responsibility and oversight of a capable professional entity. The situation for many years in the city of Shefa-Amr has been that the team responsible for waste management is overloaded with many problems occurring daily. As we can see in Table 7, Shefa-Amr has just one cleaning worker for every 8600 residents, while the budgets in the neighboring cities allow for one cleaning worker for every 2000 (Afula), 800 (Nesher), or 1166 (Kiryat Ata) residents. This shows a serious lack of budget in Shefa-Amr for cleaning, waste collection, and recycling projects. Composting systems need to be operated and maintained on an almost continuous basis. This is practically impossible with the current low number of staff in Shefa-Amr.

Table 7. Cleaning characteristics and comparison of staff for Shefa-Amr and neighboring municipalities.

	Shefa-Amr		Afula		Nesher		Kiryat Ata	
Authority area (m^2)	24,000,000		29,310,000		13,000,000		20,000,000	
# of residents	43,000 *		60,000		24,000		70,000	
# of street cleaners	(5)	1 per 8600 residents	(30)	1 per 2000 residents	(30)	1 per 800 residents	(60)	1 per 1166 residents
Intensive gardening areas	N.A.		(800)	1 per 26,000 m^2	(306)	1 per 19,000 m^2	(930)	1 per 30,000 m^2
# of gardening workers	(5)	1 per 4,800,000 m^2	(30)	1 per 977,000 m^2	(16)	1 per 812,000 m^2	(31)	1 per 645,000 m^2

* Source: Shefa-Amr municipality 2022.

3.5.3. Lack of Ongoing Budget

According to our findings, the allocated budget for waste management in Shefa-Amr is very limited, and this budget is not sufficient for handling all the waste. Thus, many conflicts occur between the municipality, contractors, and citizens, which are not always resolved. In addition, contractors are paid lump sum prices, with extra pay for extra waste. The result of this payment method is almost an inefficient waste management system. Moreover, there are no clear guidelines for the necessary optimal budget for waste management, nor for the required human power in the waste handling and cleaning unit in the municipality.

3.6. Core Competence Tree (CCT)

CCT was used to identify root competencies, based on strengths and opportunities from the SWOT analysis, for the implementation of the DC project. During this process, three core competencies were identified, as shown in Figure 4.

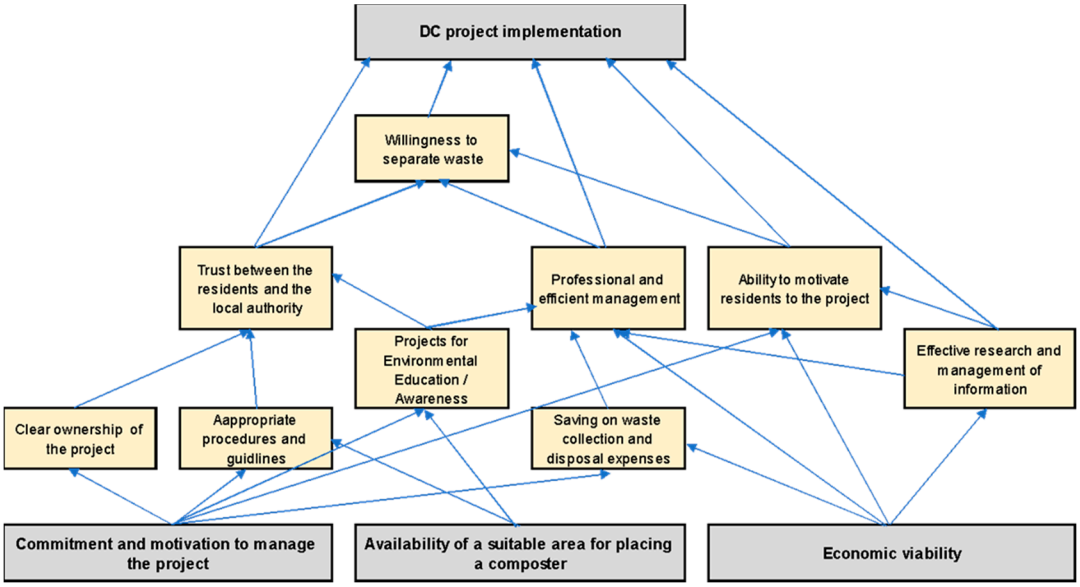

Figure 4. Core Competence Tree for the implementation of a DC project in Shefa-Amr.

According to the CCT, the commitment and the motivation of the municipality to a composting project are vital core competencies for achieving the goals of the project. That said, both the economic viability of the project and securing a suitable area for the placement of the composters are also critical for the effective implementation of the DC project.

3.6.1. Commitment to and Motivation for Managing the Project

Challenges in the city's waste management system inversely affect commitment to and motivation for the project. Thus, the existence of areas where the municipality has problematic issues with waste, specifically with organic waste, should motivate it to change the existing situation, especially if there is public interest in the change. However, the municipality of Shefa-Amr seems more interested in commercial composting than community or residential composting projects, as a result of the high economic viability of commercial organic waste composting, as was shown in our previous publication [15].

3.6.2. Suitable Areas for the Composters

This core competence is critical and has a major impact on achieving the goal of the project. It, therefore, appears as a "Go or No-Go" criterion, meaning that if such an area is not available, the whole project cannot be implemented. This area should be selected according to specific regulations and the conditions of the local environment [25–29]. If the former do not exist, then they should be adapted from other locations, locally or around the world, with successful composting projects.

3.6.3. Economic Viability

Showing economic viability in the quantitative analysis through the ost/Benefit index can help in motivating the municipality to implement the project.

The economic analysis for Shefa-Amr shows that improving the economic viability of commercial organic waste recycling depends directly on the quantities that can be collected and transported to a local facility. The transportation cost of commercial organic waste stream is very low compared with other streams [41].

4. Discussion

The effective management of OFMSW is challenging, and its feasibility from the social, environmental, and economic aspects is not always guaranteed. Decision-supporting frameworks are, therefore, essential for choosing the most suitable composting option.

The qualitative analysis methodology presented here inspects and analyzes the OFMSW arena and the various relevant conflicts and constraints in order to establish a detailed SWOT analysis. The detailed SWOT analysis helps identify core competencies (from strengths and opportunities), and root problems (from weaknesses and threats), which support decision making regarding the implementation of the DC project under consideration.

The qualitative analysis path was applied to examine and analyze the feasibility of implementing a DC project in the city of Shefa-Amr in Israel. Findings from the arena analysis (Table 1) show that stakeholders, such as the local authority, initiators and operators of urban agriculture projects, businesses, and residents, the latter being potential participants in the DC project, are key players in the efficient implementation of DC projects. Thus, the sustainability of the composting system is mainly based on the cooperation between the different actors at the various stages, and the existence of win–win situations between them.

The constraints analysis for the DC project included three alternatives which were based on the three different composting options. The findings in Table 2 indicate that data availability is a major constraint in the planning stage of composting systems, especially when exact, detailed, and timely information is needed, such as commercial waste quantities. In most cases, amounts of organic waste are only roughly estimated, which makes the planning process more challenging.

Another constraint that often appears in the literature and is expected in Shefa-Amr is the "low participation rate", which is related to lack of awareness and the lack of a regulatory framework, with the latter having the larger impact. An example of one such regulation is the "Senate Bill 1383" California state law [42]. This regulation specifies which businesses must arrange their own organic waste recycling services and how this waste should be collected, along with other clear guidelines to reduce the landfilling of organic waste.

Furthermore, resources were also considered as potential constraints. This includes not only the budget needed for purchasing the composting systems, but also the operational and maintenance costs of such systems. Operational costs can be critical for the sustainability of a composting system, since high operational costs (collection and transport costs) can potentially lead to the failure of the entire project or system.

Results of the conflict analysis, as presented in Tables 3–5, are based on both the ARENA analysis and the constraint analysis. They show that poor operation and lack of procedures and regulations, combined with the lack of public awareness, can cause many conflicts between the residents and either the local authority or the compost facility operator, or both. NIMBY is one of the most important conflicts stemming from the objection of residents to the location of the proposed facility site. In addition, poor operation can lead to environmental and other nuisances (e.g., bad odors), which may cause the closing of the composting plant. Residents object not only to potentially hazardous facilities but also to ensuing inconveniences and the potential decline in their real estate property values [43–45].

That said, residents are also pulled in the opposite direction as they try to achieve the same goal. They, too, are interested in alternative solutions to landfilling that will reduce the negative externalities (like the "uncalculated" cost of pollution) and enable the conservation of land; factors that are likely to result in a higher standard of living.

The literature shows that there are various means to reduce the residents' objections. These include but are not limited to legal proceedings, persuasion, compensation (money), public campaigns, education and information, legislation, and political proceedings, as well as mobilizing people with public status to support an idea or a plan [45–49].

The existence of unresolved root problems can lead to the failure of a sustainable composting system in Shefa-Amr. "Lack of national regulations", "clear ownership of the project", and the "lack of ongoing budget", are root problems that relate to the fact that there are no local programs to encourage composting, and no bylaws similar to the "Senate Bill 1383" to obligate big waste generators to take responsibility for their waste. A common result of the lack of regulation is the low participation rate, which leads, almost always, to high waste management costs (per weight) and other undesirable consequences [41].

Ownership of the project can be either a "root problem" or a "core competence", like a two-faced coin. No clear ownership of the project can lead to a "chain of undesirable effects", such as poor management of the sites, which can lead to odor and rodent problems. This may in turn enhance NIMBY effects and, thus, the goal will not be achieved. Clear ownership, the reverse side of the coin, is actually a core competence. Ownership and the lack of ongoing budget are issues that are more likely to appear in local authorities that suffer from distributive injustice, such as Arab local authorities in Israel, which usually have lower budgets to manage waste than their Jewish counterparts.

It should be noted that "economic viability", which is a main core competence, was the main topic of our first publication that focused on the quantitative analysis of the DCAM [15].

The commitment and motivation of the Shefa-Amr businesses was indicated by their readiness to separate, collect, and transport their own organic waste to local transit stations as "self-haulers". This indicates that commercial organic waste composting might be more effective and more economically viable in Shefa-Amr than home composting [41]. The final decision should be made after a suitable quantitative analysis of both situations [15].

The commitment and motivation of the municipality, not only of businesses, and its readiness to take responsibility for and ownership of the project are also needed to ensure the best operating conditions, with no bad odors and/or bad compost quality. Optimal maintenance and operation require the employment of professional master composter operators that can be responsible for environmental awareness efforts and urban agricultural activities. The municipality should be involved from the planning phase to cooperation in compost marketing for urban agriculture activities.

Just as important is the availability of a "suitable site for placing the compost facility". Such an area can be a local waste transfer station, or a community recycling center, or even

a community garden with sufficient space. It can also be any vacant lot that meets the required guidelines and conditions. This allows the placement of the composting system with "minimal objections".

It should be noted that the core competencies were evaluated differently for each DC solution, these being home composting, community composting, or communal composting [50]. As noted in the discussion, the qualitative analysis path reveals both the root problems and the core competencies related to the implementation of DC projects, thus proving to be a powerful tool aiding decision making in the implementation strategies and action plans for sustainable organic waste management.

5. Conclusions

In this work, we have focused on the qualitative analysis path of the DCAM. We presented the methodology, and how to enable decision makers to implement action-driven strategies for improving sustainable organic waste management.

The qualitative analysis methodology was applied in the case study for the city of Shefa-Amr and resulted in the identification of root problems and core competencies. The results for the case of Shefa-Amr show that, to run a sustainable DC project, a supporting framework must be in place, or created, encompassing certain criteria. Commercial areas seem to be a good and promising first criterion, according to the availability of organic waste, the efficiency of waste collection, and the possibility to control the participation rate. The second criterion is the existence of regulation (laws and bylaws) that support waste sorting and composting systems. Without laws that obligate citizens and/or business owners to sort and recycle their own waste, and the existence of fines for violators, these projects may be economically destined for failure.

Another important criterion is the quantity of environmental activity. Although the amount of environmental activity in Shefa-Amr is increasing, there needs to be constant awareness raising among citizens about the importance of DC projects, and about sorting waste to remove unwanted materials (such as plastic or meat).

Furthermore, the economic feasibility calculations for a decentralized composting system must include the operating and maintenance costs, and all possible relevant operational expenses (electricity, workers, transport costs, etc.), as well as periodic maintenance expenses. This is particularly important in view of the limited (low) allocated budgets in Shefa-Amr for waste management. Worst-case scenarios should be taken into account. In addition, there should be skilled personnel (master composters) who take full responsibility for monitoring and ensuring the operation and maintenance of the system, ensure that instructions are carried out daily, and deal with potential challenges during operation, such as excess quantities during certain periods, or even odors and other problems. The team responsible for waste management in the municipality of Shefa-Amr is currently overloaded due to a lack of human resources. Without such a person or body, the sustainability of the project is under serious doubt.

In general, the qualitative analysis of the DCAM showed it to be unique and innovative. It is a powerful tool for decision makers to pre-evaluate DC projects, while understanding the related root problems and core competencies. This is crucial for formulating strategies and action plans to remove barriers and promote the project effectively and ensure its further replicability and transferability. The model is universal and can be adapted and implemented in any locality, region, city, or country in the world.

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Abbreviations

AD	Anaerobic digestion
CC	Centralized composting
CCT	Core competence tree
DC	Decentralized composting
DCAM	Decentralized composting analysis model
DECOST	Decentralised Composting in Small Towns
fCRT	Focused current reality tree
GHG	Greenhouse gas
OFMSW	Organic fraction of municipal solid waste
NIMBY	Not in my backyard
PAYT	Pay as you throw
SWOT	Strengths, weaknesses, opportunities, and threats

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