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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) develops 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 the qualitative analysis as a complementary tool to support decision making, in cases where quantitative analysis is unequivocal. 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. DCAM qualitative analysis in Shefa-Amr (case study) indicates that unresolved root problems, such as the "lack of national regulation", "clear ownership of the project" and "lack of ongoing budget" can result in an unsustainable composting system. Countering that, "the 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; decentralised composting analysis model; qualitative analysis; municipal solid waste; organic waste management

1. Introduction

The Effective management strategies for the organic fraction of municipal solid waste (OFMSW) are getting more attention in recent years, 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 climate change effects 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 odours [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 prices.

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

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Over the last few decades, composting has been the most common method of treating OFMSW [8–11]. 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 done by the "windrow" technique, while decentralized composting (DC) is done by "in-vessel" composters [12].

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 [13], we presented the Decentralized Composting Analysis Model (DCAM), focusing on the quantitative analysis path.

The qualitative analysis for the implementation of Decentralized Composting (DC) projects provides an insight into and understanding of the various players and stakeholders, and their respective impacts on DC projects. It also provides an insight into understanding the interrelationships between regulation and the organic waste recycling market, with its various stakeholders. This is crucial to closing the OFMSW loop and achieving sustainable treatment processes for this fraction.

2. Methodology

The Qualitative analysis is complementary to quantitative analysis for supporting decision-making in cases where the quantitative analysis is inconclusive, or when certain aspects of the project are not easy to quantify, in other words when the quantitative feasibility or viability is not clear or guaranteed.

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.

Figure 1 shows a schematic description of the DCAM framework, which includes both the quantitative and qualitative paths, with our focus on the latter, in this paper.

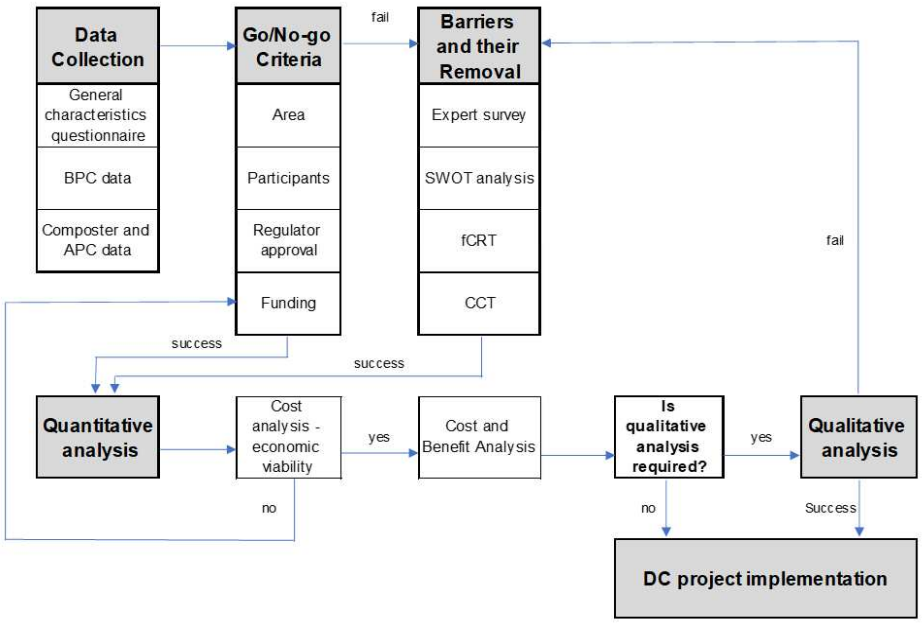

Figure 1. Schematic description of the Decentralized Composting Analysis Model (DCAM) framework. Source: [13].

The DCAM qualitative analysis path consists of the following seven steps:

1. ARENA Analysis – based on the Focused ARENA Strategy [14, 15].
2. Constraint Analysis – based on the Theory of Constraints [16].
3. Conflict Analysis – based on the Theory of Constraints [16].

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4. SWOT Analysis – based on Strengths, Weaknesses, Opportunities and Threats analysis.
5. Focused Current Reality Tree (fCRT) – based on Value-Focused Management [14, 15].
6. Current Competencies Tree (CCT) – based on Value-Focused Management [17].
7. Implementation Roadmap [16].

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

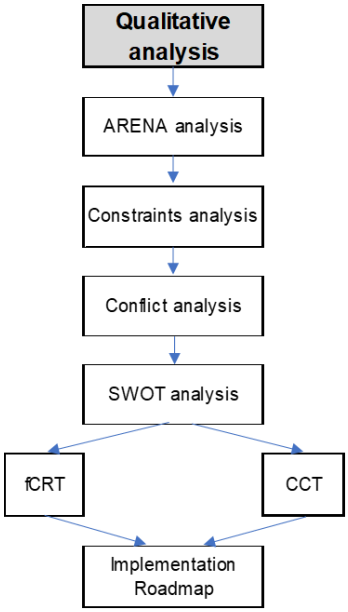

Figure 2. Schematic description of the DCAM's qualitative analysis path. Source: [13].

2.1 ARENA Analysis

The focused ARENA strategy is a tool for the analysis of a market or an industry. It includes "locating-mapping-identifying" the different stakeholders and players in the arena of the system [14,15].

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 carry out this mapping, a comprehensive survey should be carried out to collect data and documentation, such as laws, government decisions, local government tenders, contracts of local authorities with various contractors, local authorities' 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 by 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 in general, and DC in particular. 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), a constraint is defined as a limiting factor preventing a system from moving closer to achieving its goal. A clearly defined goal is, therefore, essential to identifying the most relevant and critical constraints.

Goldratt (1990) categorizes the constraints into four types [18]:

1. **Resource constraint** (bottleneck) – a resource that limits the overall system.
2. **Market constraint** – a market demand that is lower than the capacity of the system limits the system.

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3. **Failure Policy constraint** – any policy that limits the system.
4. **Idle constraint** – a situation where the bottleneck of the system is a very cheap resource relative to the rest of the 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/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 [19,20]) differ from conflicts in community or in commercial composting.

The most discussed conflicts in the literature for the various types of composting systems are [21–25]:

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

The issue of site selection for DC systems is one the most critical issue. 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/dysfunction of the composting system [21–25].

A significant conflict regarding site selection is the phenomenon known as "Not in my Back Yard" (NIMBY). This phenomenon is characterized by local objections to the location of a facility deemed "undesirable" [26, 27].

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 rate depends also 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 [28].

2.4. Strengths, Weaknesses, Opportunities, Threats

The Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis originates in the business administration discipline, but is also widely used in other disciplines, as it is an efficient analysis tool in which results can be visually displayed and effectively communicated [17, 29–31].

The SWOT analysis is the strategic analysis to identify and assess the strengths, weaknesses, opportunities, and threats in a project's internal and external environments [15,17,30,32,33]. This methodology is also used to analyze and evaluate projects, and as a basis for strategic decision-making [15,17,30,32,33]. The SWOT analysis in the current research consisted of several interviews with shareholders and stakeholders to collect information, especially at the local and regional levels.

2.5. Focused Current Reality Tree (fCRT)

The focused Current Reality Tree (fCRT) is a thinking process within the Theory of Constraints. It enables the identification of root causes that lead to most of the undesirable effects, which prevent achieving the desired/defined goals and objectives [34]. The method involves taking the undesirable phenomena from the SWOT analysis, i.e. weaknesses and threats, and forming the fCRT by making logical (causal) connections between these undesirable phenomena leading to the "goal is not achieved", and identifying one to four (1 to 4) strategic root problems that would prevent the achievement of that goal [32].

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2.6. Core Competence Tree

The Core Competence Tree (CCT) is a methodology that enables the identification of core competencies needed for achieving the desired/defined goals and objectives. This method takes the desirable phenomena - also desirable Effects [34] from the SWOT analysis, i.e. strengths and opportunities, and forms the CCT by making logical connections between the desirable phenomena that always lead to achieving the desired/defined goal. These connections reveal one to four (1 to 4) strategic core (root) competencies, which are the core strategic capabilities to be strengthened, and to which the activity must be strategically subordinated [32].

2.7. Implementation Roadmap

The last step is to develop a formal implementation plan that provides answers to overcome the root causes, and identifies the root competencies, in order to cause the required change. The implementation plan based on stakeholders help to sequence all the inputs from previous steps into a simple implementation roadmap showing the sequence and responsibilities for implementing the major injections [16]. In this article, the conclusions can be used as guideline for the 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 [35]. Approximately 32,000 tons of waste are produced in Shefa-Amr each year, of which 18,000 tons are classified, according to municipal records, as mixed household waste. 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 'Decentralised Composting in Small Towns' (DECOST) project [36].

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.

3.1. ARENA Analysis

In centralized composting 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 impact 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	Local research centers, universities, consulting firms
4	and Research	Planning bodies, Ministry of Environmental Protection
5	Lobbying and	Local authorities, NGOs (youth, women, and retirees)
6	Regulatory Approval	Food rescue associations, animal keepers, zoos

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7	Awareness Raising	Waste collection contractors, local authorities, local waste transfer stations
8	Organic Waste Reduction	Composting companies, local composting facilities, compost equipment suppliers
9	Waste Management	Green grocers, supermarkets, restaurants
10	Composting Infrastructure	Schools (certified as eco-friendly/green), Households/neighbourhoods with active gardens
11	Organic Waste	Plant nurseries, farmers' associations

The critical players in the initial stages (1-5) of any DC project are the supporting bodies (like 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 green grocers, 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 distances Identifying suitable locations Allocating budget 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 odours, pests, contamination)	Demand for end facility products Low compost quality Potential issues related to composting from waste (bad odours , 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

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			Access to land and limited space Lack of public cooperation Emphasis on centralized solid waste planning
Bottlenecks (Data)	Personnel resources, equipment and 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 in operating and building commercial composting facilities

* Commercial composting 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	Neighbours	Odour 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

Poor operation of the composter can cause odour problems and attract insects and/or mice, which is the first conflict. Moreover, the continued operation of a poorly operated composter 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).

It should be noted that the percentage of participation in home composting projects is typically not high, generally below 20% [28]. 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 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 nuisances
Local Authority	Contractor/Operating Body	Ineffective operation and maintenance

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Contractor/Operating Body	Residents	Requirements for input material and potential rejection of input material

The first conflict in community composting is the environmental and/or visual nuisances. 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 odour 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 also be operational malfunctions, especially when volunteers are unable to invest the time required to perform the work, or when the responsibility of operating and maintaining the composter changes rapidly between volunteers.

The third conflict refers to the requirements for 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. Further, compost operators and/or contractors may refuse the input material, if not properly separated.

COMMERCIAL COMMUNITY COMPOSTING

Table 5. Conflict analysis of commercial community composting.

Side 1	Side 2	Conflict
Waste Generators / Business Owners	Local Authority	Frequency of organic waste removal
Waste Generators / Business Owners	Local Authority	Rate of business owners' participation
Contractor / Operator	Waste Generators / Business Owners	Organic waste separation guidelines
Residents / Neighbours of the Business	Local Authority	NIMBY (Not In My Back Yard)
Planning Bodies	Local Authority	Lack of experience with planning permissions for composting machines / composting plants in mixed use development areas
Local Authority	Waste Generators / 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

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Operators of Composting Sites	Local Authority	Availability of ongoing budget and continuous payment for the operation

The first conflict in commercial community composting is the frequency of organic waste removal or collection. This is important in particular during weekends, shopping seasons and holidays, and even critical during the hot summer months, in order to prevent bad odours. According to the initial survey conducted in Shefa-Amr, organic waste generated by green grocers must be sometimes removed twice or more per day, which increases the transportation costs to a level that the local authority cannot 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 "excess waste bylaw", to make major waste generators pay for their increased waste 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 by-laws, 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 will double.

The third conflict is 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 area, practically in their own backyards.

The lack of local experience is also listed as a 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 getting the approval of the Ministry 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, and even close it at a later stage following approval.

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

The conflict analysis has also indicated 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 the landfill. Furthermore, there is a need for 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 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 and/or 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).

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

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		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 under planning.
Weaknesses	Social	Low Participation percentage (expected) Not in My Back Yard (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 / 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 / reducing food waste No detailed data existed about the current situation No regulations / 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 / awareness, i.e. 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 / 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 Composters operator 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

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	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	Odour 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 result is called a "fCRT". During the process, three root problems were identified.

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 ongoing budget, are all critical for achieving the goals. Without them, or even one of them, there could be undesirable consequences.

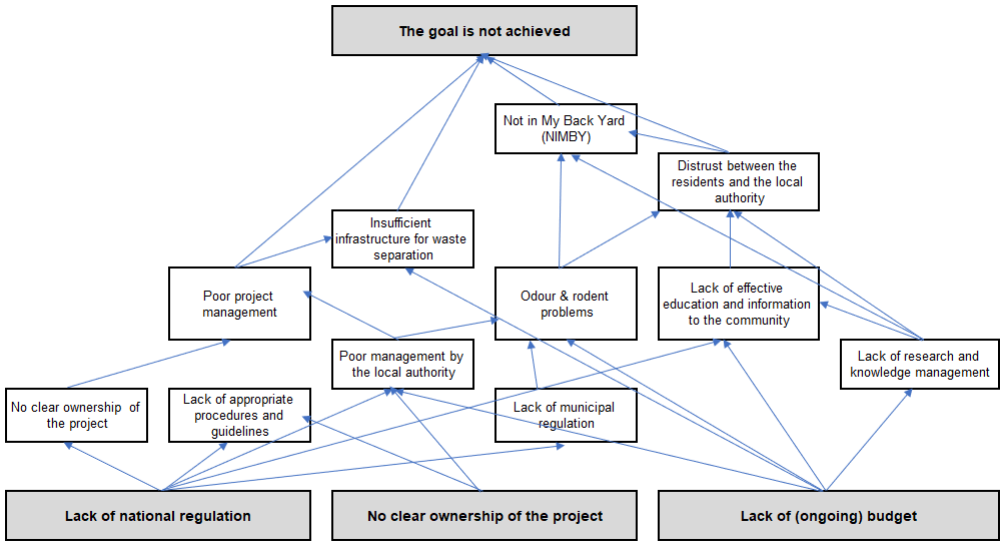

Figure 3. Focused Current Reality Tree for Identifying Root Problems in the Implementation of a DC Project.

Three root problems were identified 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 that intend 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 [13].

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3.5.2. No clear ownership of the project

To ensure clear guidelines and the professional management of the project, the project should be under the responsibility and oversight of a capable professional entity. The situation for many years in the City of Shefa-Amr is 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 8,600 residents, while the budgets in the neighboring cities allow for one cleaning worker for every 2,000 (Afula), 800 (Nesher) and 1,166 (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.

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 needed optimal budget for waste management, and also for the required human power in the waste handling and cleaning unit in the municipality.

Table 7. Cleaning characteristics and comparison of staff for Shefa-Amr and Neighbouring Municipalities.

	Shefa-Amr		**Afula**		**Nesher**		**Kiryat Ata**	
Authority's area (dunam)	24,000		29,310		13,000		20,000	
# of residents	43,000*		60,000		24,000		70,000	
# of street cleaners	5	1 per 8,600 residents	30	1 per 2,000 residents	30	1 per 800 residents	60	1 per 1,166 residents
Intensive gardening areas	N.A.		800	1 per 26 dunums	306	1 per 19 dunums	930	1 per 30 dunums
# of gardening workers	5	1 per 4,800 dunums	30	1 per 977 dunums	16	1 per 812 dunums	31	1 per 645 dunums

* Source: Shefa-Amr Municipality 2022.

3.6. Core Competence Tree (CCT)

CCT is used to identify root competencies, based on strengths and opportunities from the SWOT analysis while implementing a DC project. During this process, three core competencies were identified, as shown in Figure 4.

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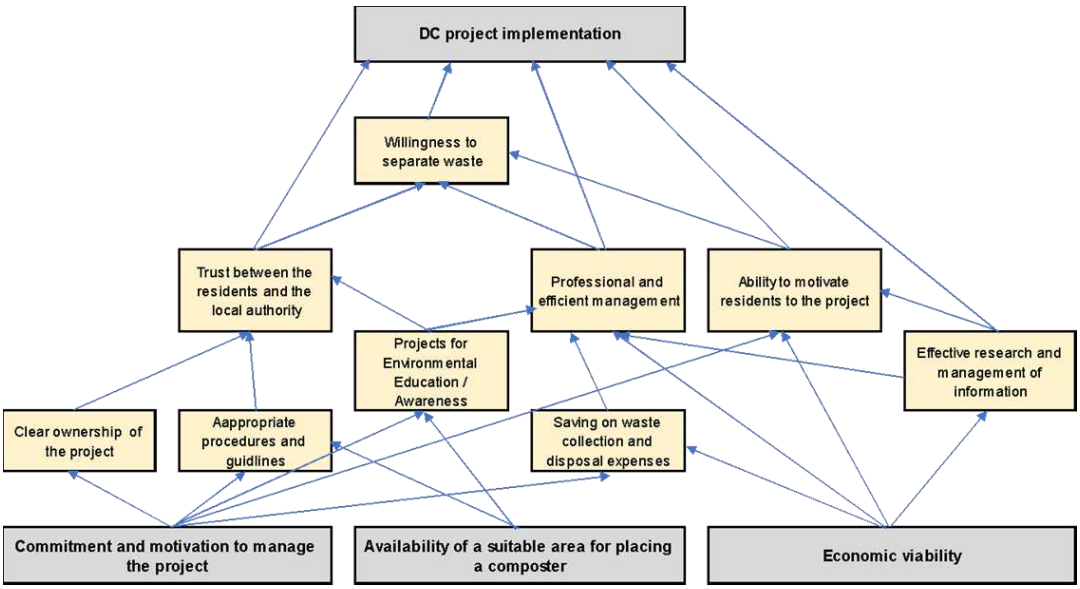

Figure 4. Core Competence Tree for the Implementation of a DC Project.

According to the CCT, the commitment and the motivation of the municipality for a composting project are among the most important core competencies toward achieving the goals of the project. That said, economic viability and the availability of a suitable area for placing the composter 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 the 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 [13].

3.6.2. Availability of a suitable area for placing the composter

- This core competence is critical, and has a major impact on achieving the goal of the project. It, therefore, appears as a "Go/No-Go" criteria, 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 "conditions" of the local environment [21–25]. If those 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 Cost/Benefit index, can help in motivating the municipality to implement the project.

The economic analysis for Shefa-Amr showed 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 [37].

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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 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 the 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 in different stages, and the existence of win-win situations between them.

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

Another constraint that appears often in the literature, and is expected in Shefa-Amr, is the "low participation rate", which is related to the lack of awareness and the lack of a regulatory framework, with the latter having the larger impact. One such regulation, as an example, is the "Senate Bill 1383" California state law [38]. This regulation specifies which businesses must arrange their organic waste recycling services, and how this waste should be collected, along with other clear guidelines to reduce the landfilling of the organic waste.

Furthermore, resources were also considered as potential constraints. This includes not only the needed budget 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 cost) can potentially lead to the failure of the entire project/system.

Results of the conflict analysis, as presented in Tables 3, 4 and 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 odours), which may cause the closing of the composting plant. Residents object not only to potentially hazardous facilities, but also to inconveniences and the decline in the value of their real estate properties [39–41].

The conflict with residents pulls them in opposite directions, as they try to achieve the same goal, since 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, on the bottom line, result in a higher standard of living.

The literature shows that there are various means to reduce the residents' objections such as 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 [42–45].

The existence of unresolved root problems can lead to the failure of a sustainable composting system in Shefa-Amr. "Lack of national regulation", "clear ownership of the project" and the "lack of

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ongoing budget", are root problems that relate to the fact that there are no programs to encourage composting, and no bylaws, similar to "Senate Bill 1383", that obligates 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 [37].

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 odour and rodent problems. This may in turn enhance NIMBY effects, 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 the "economic viability", which is a main core competence, was the main topic of our first publication that focused on the quantitative analysis of DCAM [13].

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 m ore effective and more economically viable than home composting [37]. The final decision should be made after a suitable quantitative analysis for both situations [13].

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 odours 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 the cooperation in compost marketing for urban agriculture activities.

Not less 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 composting system with "minimal objections".

It should be noted that the core competencies could be evaluated differently for each DC solution, such as home composting, community composting or communal composting [46]. As can be seen in the discussion, the qualitative analysis path enables to reveal the root problems and the core competencies for the implementation of DC projects; forming a powerful tool enabling decision-making to implement strategies and action plans for improving sustainable organic waste management.

5. Conclusions

This 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 Shefa-Amr case show that, to run a sustainable DC project, a supporting framework must be in place, or created, encompassing the following criteria:

1. Commercial areas seem to be a good and promising starting point, according to the availability of organic waste, the efficiency of waste collection, and the possibility to control the participation rate.
2. The existence of Regulation (laws and bylaws) that support waste sorting and composting systems is necessary. Without laws that obligate citizens and/or business owners to sort and recycle their waste, and the existence of fines for violators, these projects may be economically destined for failure.

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3. Although the number of environmental activities in Shefa-Amr is increasing, there needs to be constant awareness raising among citizens about the importance of DC projects, and about sorting waste, in order to avoid the presence of unwanted materials (such as plastic or meat).
4. 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.
5. There should be skilled personnel (Master Composter) 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 path of the DCAM was shown to be a unique and innovative model. It provides a powerful tool for decision-makers to pre-evaluate DC projects, while understanding root problems and core competencies for formulating both a strategy and an action plan to remove barriers and promote the project effectively. The model is universal, and can be adapted and implemented in any locality, region, city, or country in the world.

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Acronyms

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

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NIMBY Not in my Backyard

PAYT Pay as You Throw

SWOT Strengths, Weaknesses, Opportunities, and Threats

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