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Research Paper

Assessing the performance of a waste management system towards a circular economy in the Global South: The case of Marrakech (Morocco)

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ABSTRACT

Waste management is essential for the safety and wellbeing of any society; it also helps to tackle global problems, such as climate change and resource scarcity. To support the evolution of waste management systems (WMSs) towards a circular economy (CE), assessment methods are applied. This paper shows, using the case of Marrakech (Morocco), how a novel holistic approach called WMS development stage concept (WMS-DSC) is applied to assess WMSs and determine measures promoting a CE. The approach enables a simplified derivation of measures that are useful to municipal decision makers and consists of five stages; stage 1 is equal to a WMS lacking essential WM elements and stage 5 describes a functioning CE. The approach was specifically designed to be transferable to other Global South cities through the categorization into these universal stages.

The results from the WMS-DSC show that components related to energy recovery and waste recycling are classified in stage 1. For the latter, a slight development towards stage 2 can be assumed due to the planned activities in Marrakech. The components "collection and transport" and "prevention and reuse" are mainly in stage 2. Nevertheless, the components "governance", "sector and market" and "waste disposal" are assigned to stages 2 and 3 with a stronger trend towards stage 4. The results show that in Marrakech and Morocco, CE is still in its infancy, and with this current state, it is hard to achieve. However, 33 measures were determined to improve the WMS of Marrakech and promote a CE.

1. Introduction

Worldwide, population and rate of urbanization increase notably in low and middle income countries (LMIC), leading to a rapid and uncontrolled growth of megacities (UN, 2014). This poses huge challenges to the development of urban infrastructures (Zhang, 2016), including waste management (WM), which is essential to health and environmental protection. Independent of the income level, countries with structural problems in WM or generally disadvantaged or underprivileged countries (Schneider, 2017) can be categorized as countries of the Global South (GS).

Urban WMSs (waste management systems) in GS countries perform poorly, resulting in lack of area-wide waste collection, safe waste disposal (Ferronato and Torretta, 2019; Kaza et al., 2018), clear

Abbreviations: C&D, Construction and demolition; CE, Circular economy; CEV, Disposal and recovery center (*Centre d'élimination et de valorisation*); CMUR, Circular material use rate; CT, Collection and transport; DR, Diversion rate; DRE, Regional Environmental Department (*Direction régionale de l'environnement*); EoL, End-of-life; EPR, Extended producer responsibility; ER, Energy recovery; G, Governance; GS, Global South; LMIC, Low and middle income countries; MSW, Municipal solid waste; MTEDD, Moroccan Ministry of Energy Transition and Sustainable Development; PNDM, National Program of Household and similar waste (*Programme National des Gestion des Déchets Ménagers et Assimilés*; PNVD, National Program for the Recovery of Waste (Programme National de Valorisation des Déchets); PPP, Public private partnership; PR, Prevention and reuse; RDF, Refuse-derived fuel; SIREDD, Regional Information System on the Environment and Sustainable Development (Système d'Information Régional sur l'Environnement et le développement durable); SM, Sector and market; SNDD, National Strategy for Sustainable Development 2030 (Stratégie nationale de développement durable 2030); SNRVD, National waste reduction and recovery strategy (Stratégie Nationale de Réduction et de Valorisation des Déchets); WD, Waste disposal; WM, Waste management; WMS, Waste management system; WMSs, Waste management systems; WMS-DSC, Waste management system development stage concept; WR, Waste recycling; ZWI, Zero Waste Index.

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structures, responsibilities and regulations at different political levels (Marshall and Farahbakhsh, 2013). In the past, WMS projects in GS countries often focused exclusively on implementing treatment facilities for pollution-abating (Independent Evaluation Group, 2017). Besides technological constraints, lack of qualified personnel, and absence of legal basis (Pfaff-Simoneit, 2012; van de Klundert and Anschütz, 2001; Wilson, 2007), which often prevented the integration of projects into the existing WMS (Filho et al., 2016; Pfaff-Simoneit, 2012), cost recovery and institutional capacity are also relevant factors influencing the success of projects (Independent Evaluation Group, 2017; Lerpiniere et al., 2014).

Regarding the African continent, Godfrey et al. (2019) stated that failures in governance and organizational weaknesses are evident reasons for the mismanagement of solid waste. Consequently, the improvement of administration and government functions (Ma and Hipel, 2016) through capacity building (Independent Evaluation Group, 2017; Lerpiniere et al., 2014) is suggested and also reflected in the UN's Sustainable Development Goal 17.9.

Global problems, such as climate change and resource scarcity, have led some countries, like the member states of the European Union (European Commission, 2020), to start transforming their linear WM continuously into a circular economy (CE). The basic idea behind CE is to reduce waste and its negative impacts to a minimum and keep materials and products as long as possible in the economic cycle (Kirchherr et al., 2017; Korhonen et al., 2018). Many European countries believe that CE has large potentials in terms of prosperity, job creation, economic growth and increase of competitiveness (European Commission, 2020). In the European Green Deal, the European Commission pledged to support GS countries (e.g., in Africa) to exploit their CE potentials by increasing and strengthening cooperation with them (e.g. diplomatic, trade, joint initiatives) (European Commission, 2019).

Twelve African countries already have policies to promote CE and exploit its benefits (Rademaekers et al., 2020). For example, Morocco has made great efforts to improve its WMS in order to reduce environmental impact (Diaco et al., 2020). European policies were used for guidance, and even though CE aspects are addressed in Moroccan policies and strategies, CE is still in its infancy (Diaco et al., 2020). In the last 20 years, Morocco has undergone a remarkable industrial and infrastructural evolution; the increasing industrialization and urbanization has led to a rise in the volume of waste, which is still mainly landfilled (Monnerjahn, 2019). Moreover, the recycling rates of waste are very low due to the absence of segregation at source, sorting and treatment plants. In this context, waste collectors, especially from the informal sector, play a significant role, since they take part in waste collection and sorting. In Morocco, CE potentials are estimated to be very high, as the existing system is not yet designed for reuse and recycling (Diaco et al., 2020). Besides countries, municipalities have an essential function as they ultimately contribute in realizing the exploitation of CE potentials at local level.

To analyze the WMSs and CE potentials of countries and cities, assessment methods such as life cycle approaches, multi-criteria decision tools and benchmarking methods (Allesch and Brunner, 2014; Campitelli and Schebek, 2020) are essential. The suitability of each method varies, especially considering the needed data, which is often lacking in the GS (Zurbrügg et al., 2014). Depending on the framework conditions, benchmarking tools can be used to overcome this lack. It is not surprising that in the last few years, benchmarking methods to assess WMSs and CE in GS countries were published (Campitelli et al., 2022; Fatimah et al., 2020; Whiteman et al., 2021). All the methods have one thing in common: they divide WMSs into levels, with CE being the final achievable level of WM development. While the approaches of Fatimah et al. (2020) and Whiteman et al. (2021) are useful for a rapid WMS analysis, the framework of Campitelli et al. (2022) enables a more in-depth analysis to assess the WMS performances of cities and goes further regarding the level of detail.

The aim of this paper is to demonstrate the advantages of the approach called WMS development stage concept (WMS-DSC), proposed by Campitelli et al. (2022), using the specific case of Marrakech (Morocco). The selection of Marrakech as a case study is motivated by a joint project between the Technical University of Darmstadt and the University Cady Ayyad, among others, called Trans4Biotec; the WMS assessment of the city of Marrakech was a part of the project. From this concept and the detailed investigation of the WMS of Marrakech, recommendations for action are formulated. They can be used by municipal decision makers to promote a CE in the city of Marrakech.

2. Materials and methods

As the depth of detail of the WMS-DSC analysis is profound compared to other studies using benchmarking tools (Campitelli and Schebek, 2020; Fatimah et al., 2020; Whiteman et al., 2021; Wilson et al., 2012), in this study, the WMS-DSC approach of Campitelli et al. (2022) is used to assess the WMS of Marrakech. In this section, the WMS-DSC approach, the case city of Marrakech and the data acquisition for the analysis are briefly described.

2.1. WMS-DSC approach

The WMS-DSC comprises five development stages (see Fig. 1). Stage 1 exemplifies a WMS with the worst and stage 5 with the best performance. In other words, stage 5 describes a functioning CE. The lower the stage, the further away the WMS is from a CE.

The WMS is defined by seven WMS components and 53 associated subcomponents (Table 1). The individual subcomponents are described for all stages in a scanning matrix. More detailed information regarding the WMS-DSC and the scanning matrix can be found in Campitelli et al. (2022).

To use the WMS-DSC, the following six steps are needed (Campitelli et al., 2022). In the first step, the objective(s) of the investigation have to be defined. They could be 1) the analysis of the current WMS state and identification of suitable optimization measures, 2) the analysis of existing preconditions to implement specific measures, 3) monitoring the progress or 4) comparing different WMSs. Next, the system boundary of the study has to be defined (e.g., assessed political scales and examined WMS components). The third step consists of assessing the case study by using the WMS-DSC checklist (see S1), which is the basis to determine the stages in step 4. In the checklist, some subcomponents' criteria are underlined, which represent important milestones that are essential in building up a WMS or achieving a CE. An exact stage determination is promising when all characteristics of the stage are met. In Table 2, the analysis results are visualized; if the cells are marked dark blue, the criteria of a subcomponent are completely met; if they are white, they are fully not met. All the other combinations are equal to partly met and are marked light blue. If different stages are blue or light blue for a subcomponent, then an exact determination is not possible and the range has to be mentioned. Depending on the selected objective in step 1 and based on the stage determination, specific optimization measures can be determined in step 5. If a large number of measures is identified, it is preferable to group them into clusters. The derivation of the measures is done by identifying the missing milestones (underlined criteria, see S1) and considering the criteria of higher stages. The formulated measures can be then categorized into two groups: essential and relevant. Essential measures are those that are declared as milestones in the WMS-DSC tool. All other measures are classified as relevant. The sixth and last step is an optional step, which assigns the analysis results or the recommendations for action to the SDGs.

2.2. Description of the case study: Marrakech (Morocco)

According to the World Bank income classification, Morocco is classified as an LMIC (World Bank, 2020). Tourism, agriculture and manufacturing are important sectors of the Moroccan economy. In 2018,

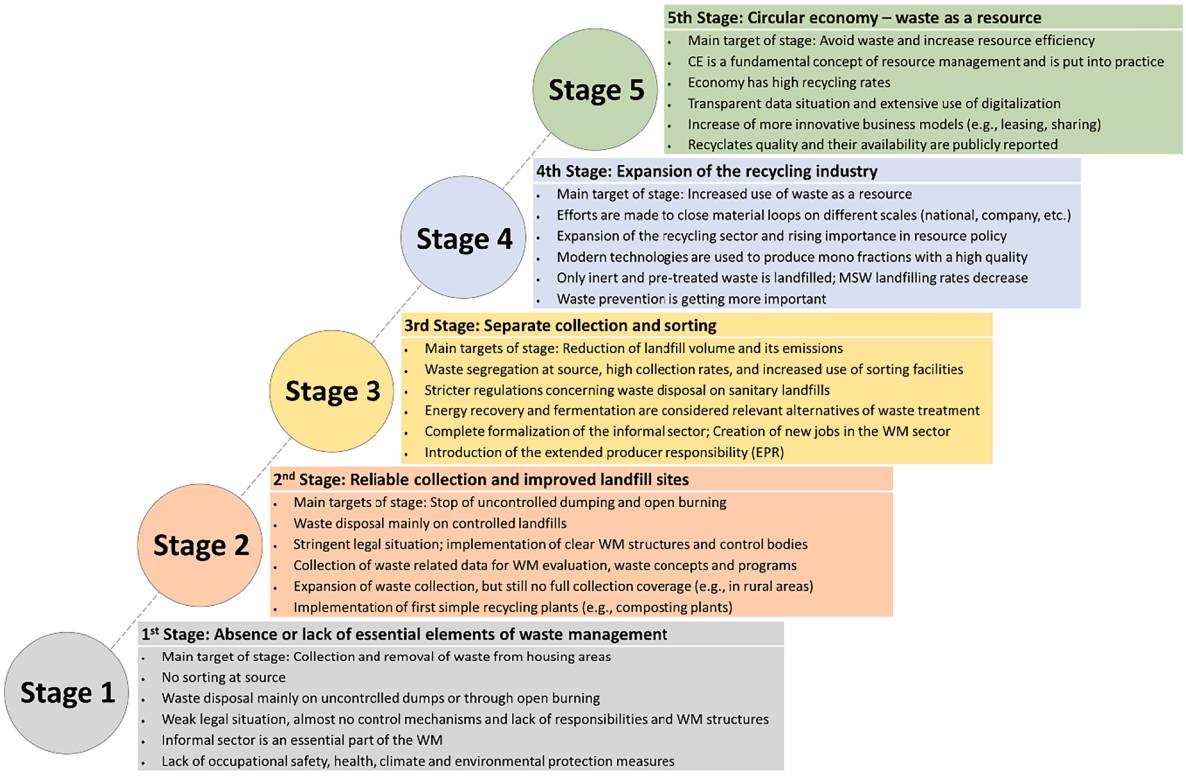

Fig. 1. Short description of the five stages of the WMS-DSC according to Campitelli et al. (2022).

Morocco's GDP per capita reached 3361.22 US dollars, and the economic growth was estimated at 1.7% (World Bank, 2020). The prefecture of Marrakech (a prefecture is an administrative division in Morocco) is the 4th biggest city of the kingdom of Morocco and the capital of the Marrakech-Safi region. Besides the prefecture of Marrakech, seven provinces belong to the region, which in the last census of 2014 had a population of 4,520,569 inhabitants. The city of Marrakech had 928,850 inhabitants (HCP, 2014). Projections by the United Nations indicate that the population in Marrakech will rise to about 1,270,000 by 2035 (UN, 2018). In the prefecture of Marrakech, 379,277 tons (SIREDD, 2022a) of municipal solid waste (MSW) were generated in 2015. The waste generation rate of 2015 is the only reported waste generation rate in the official statistics. More recent official data are not provided by regional statistical authorities. The largest share of the MSW in Marrakech is organic waste (see Fig. 2) (Ouchen, 2018).

2.2.1. Objective and system boundary of the study

The objective of this study is to assess the current WMS state of the whole prefecture of Marrakech (Fig. 3) and identify suitable optimization measures and recommendations for action to promote a CE. Besides the municipal scale, the assessment includes also the analysis on the regional (Marrakech-Safi region) and national (Morocco) level. Through the top-down connection, decisions at higher levels can directly affect the practice at the municipal scale. For this study, all six WMS components are investigated.

2.3. Data acquisition and data analysis

To perform the analysis, desk research and a semi-structured interview to collect the data for the WMS analysis were carried out. The complete analysis was conducted between July 2021 and March 2022. A variety of data sources were used to perform the analysis using the WMS-DSC excel sheet of Campitelli et al. (2022). Each WMS-DSC component was analyzed individually. With regard to the investigated issue, data and information were sought in English and, if not available, in French at all political levels. For this purpose, publicly available reports or government documents related to WM and CE in English and French were searched for on google and on the official websites of WM-responsible ministries (especially the Moroccan Ministry of Energy Transition and Sustainable Development - MTEDD) and the municipality of Marrakech. Due to the fact that legal texts were not always available in French, some had to be evaluated in Arabic. Moreover, scientific studies on WMS analysis regarding Marrakech, Marrakech-Safi and Morocco were searched for. Statistical WM data for Marrakech or the region of Marrakech-Safi were, if available, used, ranging from WM reports to the establishment of the Regional Information System on Environment and Sustainable Development (SIREDD). Due to the fact that not all information could be found in the sources mentioned before, articles from newspapers and information on websites have also been integrated. Furthermore, because of the lack of publicly available data regarding CT, WD, ER and WR, a semi-structured online interview was conducted in 2021 with Redouane Rifki, the plant operator of the disposal and recovery center "CEV" (Centre d'élimination et de valorisation) managed by Ecomed. In the CEV, all the wastes of the city of Marrakech are treated and disposed. The interview questions were based on the missing criteria of the WMS components, which are needed for stage determination. Through the answers, the criteria could be directly classified into met, partly met, not met or not available.

All the used sources for the analysis, the results, and the stage ranking for each WMS (sub-) component are provided in the excel sheet (S1). The used sources are named in the columns L/M and listed in the excel folder "References". It also includes the rationale for selecting each criterion.

3. Results and discussion

In this section, the results of the WMS analysis (Table 2 and Table 3) using the WMS-DSC for the city of Marrakech are presented and discussed. This section is organized based on the seven WMS components. In this section, only a selection of the analyzed subcomponents is

Table 1
Short description of the WMS components.

WMS component	description
Governance "G"	All measures that are needed to manage, control and regulate WM at the municipal, regional or national level. For example, laws, regulations, policy and financial instruments, waste plans, programs, concepts, authorities, and other supervisory bodies, institutions, or WM services. This component is divided into 16 subcomponents assigned to four groups: • Legislation and other policies • Administration and monitoring • Education and research • Occupational safety, health and environmental protection
Sector and market "SM"	All market activities and aspects concerning WM (including recycling markets, import and export of waste, employment); the structuring of the WM sector (including public and private company structures); the integration of the informal sector; financial funding of WM activities and waste projects; trading and broking of waste products or secondary raw materials and fuels.
Collection and transport "CT"	Measures such as the collection of waste systems (e.g., door-to-door), separation at source of different waste types (MSW, hazardous waste, C&D, etc.), and their transportation and storage (e.g., transfer stations) are included here. Also, aspects concerning service providers, collection efficiencies and collection rates are included.
Waste disposal "WD"	All measures and aspects regarding the disposal of waste (open dumping, open burning, landfilling, and other means of disposal), the different qualities of landfilling, and leachate and landfill gas management are included.
Energy recovery "ER"	Aspects and measures of plants that use waste as a fuel (like the controlled incineration of waste to produce thermal or electrical energy), co-incineration and the conversion of refuse-derived fuels (RDFs) into energy as a substitute for fossil fuels are described here.
Waste recycling "WR"	Measures to recycle different wastes, such as composting, fermentation, sorting and other recycling plants (especially material recycling), are described here as well as recycling rates, diversion rates (DR) and the circular material use rate (CMUR).
Prevention and reuse "PR"	Measures to prevent waste and promote reuse activities as well as innovative business models, such as sharing and repairing and efforts of companies regarding the optimization of processes and products (product design), are included here. It also comprises indicators such as waste generation and Zero-Waste-Index (ZWI).

presented as well as the stage classification for every WMS component. Nonetheless, all subcomponents were analyzed, and the detailed analysis results as well as the rationale for each result can be found in the supplements (S1).

3.1. Governance

Based on the results, the component "governance" is considered to be mostly in stage 2 to stage 3 (Table 2) for the city of Marrakech and higher political levels. The rationale for classifying governance aspects in these stages are described for the most relevant subcomponents.

Waste in Morocco is an important emission sector, which was declared a national priority (Climate Chance, 2020). Moreover, Morocco is very active in defining the legal WM framework and already has a good foundation with Law 28-00, which deals with waste (Royaume Du Maroc, 2006), seven other laws and decrees, eleven orders and nine regulations. WM related and time dependent targets, relevant waste concepts, WM responsibilities and stakeholders are legally defined. With Law 99-12, Morocco introduced an ecological tax on plastic articles in 2014, while in 2015, with Law 77-15, the country banned plastic bags. Other laws regarding the management of construction and demolition (C&D) waste are in preparation (Rademaekers et al., 2020). So, WM laws and regulations exist, but they have numerous gaps that need to be closed in order to establish a CE, e.g., by implementing measures or instruments promoting recycling, as anchored in the 5-stage waste hierarchy in Law 28-00. or introducing the extended producer responsibility (EPR). As a result, G1 and G2 are classified fully at stage 2 and partly at stage 3.

Based on the fact that Morocco, through Decree no 2-07-253, stipulated a detailed nomenclature for waste types and indicated hazardous wastes, the subcomponent G.3 is assigned to stage 3.

Different national programs and strategies related to waste are in place, such as the National Program of Household and Similar Waste (PNDM), the National Strategy for Sustainable Development 2030 (SNDD), the National Program for the Recovery of Waste (PNVD) and the National Waste Reduction and Recovery Strategy (SNVRD). They all aim to improve the waste management system in Morocco, by reducing emissions from WM and better exploiting the recycling potential, which will help to raise the sustainability of the WMS and enhance the move towards a CE. According to Rademaekers et al. (2020, p. 13), Morocco is working on a roadmap towards a CE within the framework of a green economy plan. Even though CE aspects are integrated in the PNVD and SNVRD, CE is not yet the main target of Law 28-00. In regard to its public institutions, Morocco is well-positioned. At the national level, the MTEDD is mainly responsible for WM. It elaborated the SNDD and participates in the development, implementation, monitoring and evaluation of national environmental programs (such as PNVD, PNDM and SNRVD) (MTEDD, 2022). At the regional level, the Regional Directorate of Environment in Marrakech-Safi region, which is one of the deconcentrated services of the MTEDD, is responsible for WM issues (SIREDD, 2022b), whereas at the municipal level, the management, disposal and recovery of household and similar wastes was entrusted in 2020 to an establishment known as Grand Marrakech, involving intercommunal cooperation (mapecology, 2020). By law, prefectural or regional master plans for WM and regional master plans for the management of non-hazardous industrial, medical and pharmaceutical wastes, ultimate, agricultural and inert wastes should exist, but they could not be found online. Therefore, the subcomponent G.4 concerning national WM is partly met for stage 2 to stage 4, while G.5 and G.6 regarding regional and municipal WM are partly met for stage 1 to stage 3.

Environmental control (including waste issues) is the responsibility of the Secretariat of State in charge of sustainable development, based on Decree 2-14-758 of 2014, and the Directorate of Control, Environmental Assessment and Legal Affairs. The mission of the directorate is to ensure the application of legislation and regulations in environmental matters by regularly carrying out controls and inspections. At the regional level, the Environmental Impact Assessment and Monitoring Service, which is under the Regional Environmental Department (DRE) of Marrakech-Safi, is responsible for carrying out environmental inspections and control operations. Hence, the basic conditions are met regarding control authorities, monitoring of WM activities and identifying violations of rules, but the frequency of controls and their effectiveness could not be determined, among other things; therefore, G.8 is partly attributed to stage 2 to stage 3.

For the analysis of G.11 (data collection, reporting and evaluation), SIREDD is crucial. SIREDD is the operational entity of DRE, and it provides alphanumeric and cartographic data and information concerning environmental topics, such as waste and biodiversity, uniformly for all Moroccan regions (SIREDD, 2022b). However, it is not clear how this data is used at the national level. Concerning waste data, the SIREDD of Marrakech-Safi has a waste-related database with nearly 30 indicators concerning waste and leachate generation, collection, recycling and disposal rates for MSW, agricultural, industrial hazardous, medical and pharmaceutical wastes. Also, indicators such as the number of treatment plants, illegal dumps, active landfills, rehabilitated and closed landfills are available. Out of these indicators, data are available for only 10, and they are predominantly not up-to-date. The various provinces of the Marrakech-Safi region are mapped, but not continuously for all regions and for a long period of time, leading to great data gaps (SIREDD,

Table 2
Analysis results for Marrakech for the components G and SM.

1st Stage: Absence or lack of essential elements of WM **2nd Stage**: Reliable collection and improved landfill sites **3rd Stage:** Separate collection and sorting **4th Stage**: Expansion of the recycling industry **5th Stage:** Circular economy – waste as a resource		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Governance	G.1 Duties and targets					
	G.2 Laws, Regulations and Agreements					
	G.3 Nomenclature					
	G.4 National level WM					
	G.5 Regional level WM					
	G.6 Municipal level WM					
	G.7 Stakeholder cooperation					
	G.8 Control mechanisms					
	G.9 Authorization and public participation					
	G.10 Quality standards and threshold values					
	G.11 Data collection, reporting and evaluation					
	G.12 Education					
	G.13 Research					
	G.14 Awareness building					
	G.15 Occupational health and safety					
	G.16 Environmental protection					
Sector and Market	SM.1 Sector development					
	SM.2 Jobs					
	SM.3 Informal sector					
	SM.4 WM system structure and organization					
	SM.5 Financial funding					
	SM.6 Enterprises					
	SM.7 Recycling market					

	Subcomponent is met
	Subcomponent is partly met
	Subcomponent is not met or data is not available

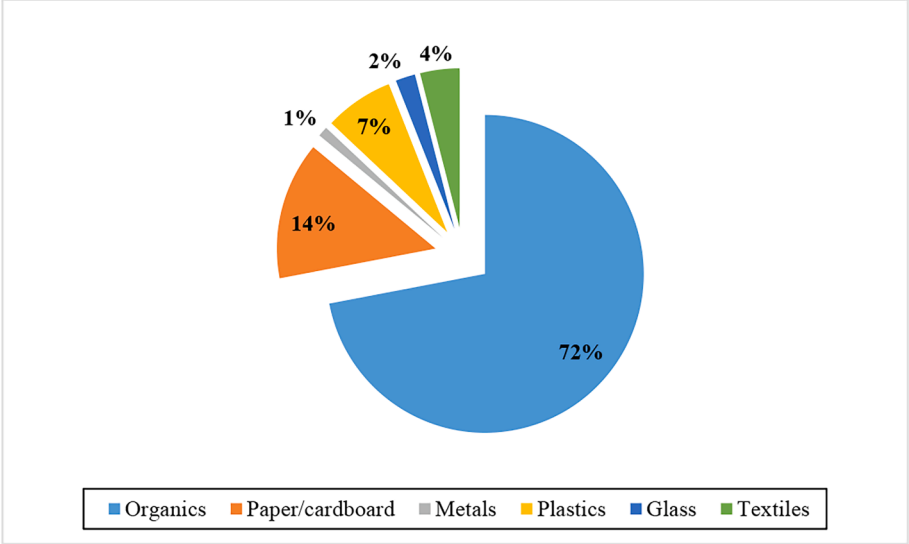

Fig. 2. MSW composition of Marrakech in 2017 (Ouchen, 2018).

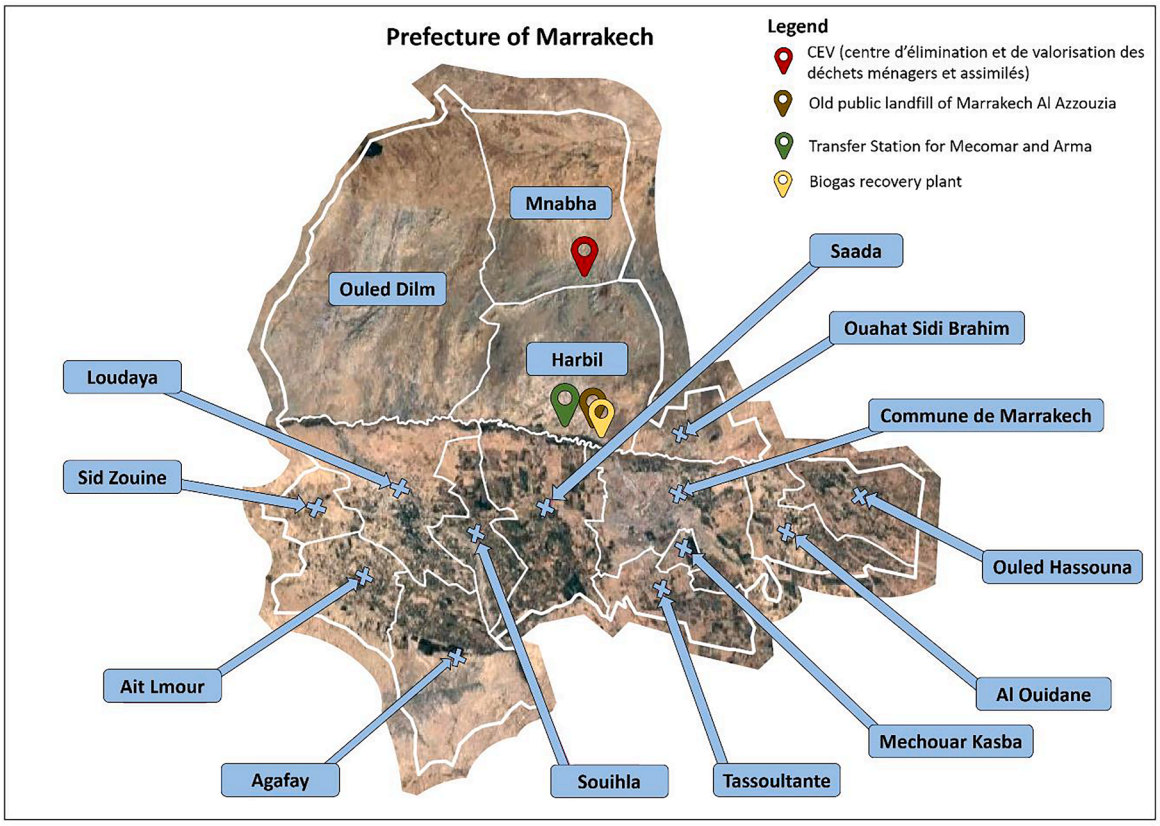

Fig. 3. Visualization of the investigated prefecture of Marrakech, including the landfills, recycling centers and transfer stations (adapted from Redouane Rifki).

2022a). Therefore, G.11 was classified as partly met for stage 2 and stage 3.

Morocco has taken action to improve recycling and WM over the last decade. Alongside these efforts, the authorities are also trying to change the behavior of the population and raise awareness concerning waste, e.g. through the PNDM and specific campaigns (Diaco et al., 2020). In this regard, many actions were taken to raise awareness about WM and CE, such as the creation of the Association of Educators of Life and Earth Sciences of Morocco (AESVT Maroc), which is a non-profit organization pushing educational projects promoting sustainable development. However, WM and CE are not that significant in society (Diaco et al., 2020), so more efforts are needed to raise awareness regarding waste prevention, sorting at source and recycling. This becomes unavoidable when the waste collection system in Marrakech enables sorting at source with more than one bin (see 3.3). Hence, G.14 (awareness building) was ranked as partly met for stage 2 and stage 3.

3.2. Sector and market

This component refers to the city of Marrakech, higher levels as well as the company level. Sector and market is between stages 2 and 3; also, stages 1 to 4 are partially met for specific subcomponents (see Table 2).

In Morocco, WM is recognized as a sector and defined in the Moroccan Nomenclature of Activities as part of sector E, "water production and distribution; sanitation, waste management and depollution" (Haut-Commissariat au plan, 2012). Moreover, waste is an important issue not only for the institutions but also for other stakeholders. The Coalition for the Recovery of Waste (COVAD) was created in April 2016, bringing together stakeholders from the private sector, civil society and government bodies to promote CE in WM at the national and international levels (Diaco et al., 2020). Therefore, stakeholder dialogues and an exchange addressing WM and CE challenges exist. The subcomponent SM.1 (sector development) is fully classified in stage 2 and stage 3.

In Marrakech, an Ecocenter is planned; besides recycling and recovery of waste, it aims to ensure the legal recognition of the profession of waste collectors and to structure their work within a cooperative framework to encourage the creation of micro-enterprises in the field of recycling. With its construction, new jobs in the recycling sector in Marrakech are expected (Ouchagour, 2021). The informal workers play an important role in the waste sector, and they are organized as small communities. But until now, there is no official association that represents the interests of waste pickers. Due to these results, SM.3 (concerning the informal sector) is partly met for stages 1 to 3.

The current Moroccan WMS is a linear economy, which can be changed in future, through a paradigm change, to achieve a CE. For this reason, a structural change is necessary, which means, on the one hand, dividing tasks (e.g. public private partnership - PPP) and, on the other hand, unifying competences to make the challenges financially viable (EcoActu, 2019). Therefore, the integration and cooperation of public and private actors is important. Law 86-12 of 2015 regulates the PPP activities in Morocco, but in 2020, Law 46-18 was promulgated, which amends and supplements Law 86-12. Numerous changes were made to increase PPP in Morocco (MEF, 2020). Presently, due to the missing EPR, there is no established system that fulfills disposal and recycling obligations of manufacturers, retailers and distributors in Morocco. Accordingly, SM.4 is categorized partly in stage 3.

Overall, the recycling market is not clearly structured. However, the plastic recycling sector in the informal sector of Morocco is highly structured (GIZ, 2019). Moreover, Morocco has introduced export licenses for specific recyclables (e.g. wastepaper and PET bottles) to ensure waste supply for national recycling industries (Diaco et al., 2020). Regarding the trading of waste, it is essential to mention Art. 42 of Law 28-00, which regulates the import of hazardous waste. It describes the import and export of hazardous waste and defines their authorization authorities. In Decree 2-17-587, the criteria and

Table 3
Analysis results for Marrakech for the components CT, WD, ER, WR and PR.

1st Stage: Absence or lack of essential elements of WM **2nd Stage**: Reliable collection and improved landfill sites **3rd Stage:** Separate collection and sorting **4th Stage**: Expansion of the recycling industry **5th Stage:** Circular economy – waste as a resource		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Collection and transport	CT.1 Waste collection					
	CT.2 Service provider					
	CT.3 Collection rates					
	CT.4 Separate collection					
	CT.5 Collection of recyclables					
	CT.6 Waste transport					
	CT.7 Transfer stations					
	CT.8 Collection of hazardous wastes					
Waste disposal	WD.1 Waste disposal					
	WD.2 Operational measures					
	WD.3 Leachate water management					
	WD.4 Landfill gas management					
	WD.5 Other means of disposal					
Energy recovery	ER.1 Thermal disposal and energy recovery					
	ER.2 Incineration plants					
	ER.3 Energy and raw material recovery					
Waste recycling	WR.1 Waste recycling					
	WR.2 Composting					
	WR.3 Fermentation					
	WR.4 Sorting and recycling plants					
	WR.5 Refuse derived fuel					
	WR.6 Recycling of construction and demolition waste					
	WR.7 Recycling rates					
	WR.8 Diversion rate and circular material use rate					
Prevention and reuse	PR.1 Prevention					
	PR.2 Circular business and usage models					
	PR.3 Product design					
	PR.4 Process optimization and operational disposal strategies					
	PR.5 Waste generation					
	PR.6 Zero-waste index					

procedures for granting such authorizations are defined (Morocco-export.com, 2019). Concerning the import of combustible waste, MTEDD is responsible for the authorization (e.g. tires, a waste-to-energy source) (Salamy Bebila, 2020). Subsequently, SM.7 is assigned partly to stages 2 to 4.

3.3. Collection and transport

In contrast to the last two components, this analysis refers predominantly to the municipal level. The results (Table 3) show that CT can be classified in stages 1 to 2 because in Marrakech, there is no separate collection at source, and all types of wastes are collected in one bin; consequently, collection rates for recyclables are not available. A model project to implement separation at source is planned in a district of Marrakech (Rifki, 2021). Moreover, although the collection of MSW is mostly done by the formal sector, the informal sector plays a significant role in waste collection in Marrakech. They are relevant in filling collection gaps, e.g. in rural areas, and in collecting recyclables (plastics, metals, glass, etc.) separately. The collection is done using uniform aboveground systems as well as placing waste in bags or boxes in front of the door (especially in the Djemaa el-Fna). The collection trucks of the formal collection firms are modern and equipped with automation and compactors. Moreover, there are plans to double the collection capacity by increasing the number of vehicles and staff, using GPS technology to monitor the collection performance, introducing feedback systems and raising the awareness of citizens regarding cleanliness of the city (Yahya, 2021). Two transfer stations exist in Marrakech for waste transfer from small to bigger trucks. There are plans to employ equipment for waste transfer and restrict access to the public (Rifki, 2021), which will also reduce the picking out of recyclables by the informal sector (Rifki, 2021).

Some aspects are partly met for stages 3, 4 and 5 (Table 3). For CT.3, the analysis results indicate that some aspects are partly met for stage 1 and stage 5 because, on the one hand, Marrakech city has the highest MSW collection rate in the Marrakech-Safi region with 100% (Rifki, 2021; SIREDD, 2022a), but on the other hand, there is no collection rate

available for rural areas, which is equal to stage 1.

3.4. Waste disposal

WD is mainly classified in stage 2 (WD.1, WD.2 and WD.4) and stage 3 (WD.5) (Table 3), even though various (but not all) criteria are also met in stage 3 for WD.1 and WD.2 (see S1).

Since 2015, the generated household and assimilated wastes of Marrakech are fully disposed of in the controlled landfill El Mnabha, which is located 42 km from Marrakech. This landfill has replaced the uncontrolled Al Azzouzia landfill, which was closed in 2016 after rehabilitation (Saadoun et al., 2021). El Mnabha landfill is part of the waste elimination and recycling center (*Centre d'élimination et de valorisation - CEV*) in Marrakech, which is operated by Ecomed. Due to the introduction of landfill classes, the disposal of non-hazardous household and assimilated wastes (landfill class 1) is allowed. But the discharge of waste with hazardous contents cannot completely be prevented (Rifki, 2021). Before disposing the incoming waste, it gets registered and weighted. The relevant waste data are documented (e.g., waste amount and type) and forwarded to the municipality, but the statistics are not being published so far. The disposed waste is compacted and covered daily with soil. No open burning of waste occurs on the landfill. Generated landfill gas is flared and not used to produce energy because the landfill was intended to dispose pretreated (mostly inert) waste (Rifki, 2021).

Due to existing gaps in waste collection, e.g., in rural areas, open burning and dumping of waste are possible ways by which citizens discard their wastes. C&D waste is mainly dumped openly (Rifki, 2021). For WD.5, stage 3 was selected because waste burning and dumping on high seas and coastal waters are prohibited, but they still can take place.

The subcomponent WD.3 (leachate water management) was classified as partly met in stage 1 and stage 2 because the active El Mnabha landfill is equipped with a basin to collect the generated leachate, but it is not further treated. The construction of leachate treatment units is planned for 2022, but until now, the remaining leachate is evaporated like in the rehabilitated Al Azzouzia landfill. Surface and groundwater monitoring is done twice a year (Rifki, 2022).

3.5. Energy recovery

Currently, Marrakech does not have any incineration plants for thermal or energy recovery from waste. During the city's analysis, no information could be found on whether waste-to-energy facilities are planned or prospectively desired. Some essential criteria for the implementation of a waste incineration plant are in place, such as the systematic collection of waste and the presence of controlled landfills. It is unclear whether qualified staff for the operation of all processes of an incineration plant is available. Due to the high organic fraction of the waste of Marrakech, it is not clear if the heating value of at least 7 MJ/kg is met (Rand et al., 2000). Therefore, more detailed and current analyses concerning waste composition and characteristics would be appropriate. However, other energy recovery options are conceivable, in terms of refuse derived fuels (RDFs), which could be pursued further. Nevertheless, there is a cement plant in Marrakech that also co-incinerates waste. Among other things, old tires or RDF are used for co-incineration. Based on these results, the subcomponents ER.2 and ER.3 are at stage 1 and ER.1 is partly in stage 1 and stage 2 (Table 3).

3.6. Waste recycling

The situation for WR is similar to ER. Majority of the subcomponents are assigned to stage 1; however, for WR.4 and WR.6, aspects of stage 2 are partly met (Table 3).

The collection of recyclables from households is done by the informal sector. Marrakech has a sorting facility (CEV), which was completed in 2017 and started work in 2020 (Rifki, 2021). It consists of two conveyors, each with a throughput of 400 tons per day (Rifki, 2021). In addition to a bag opener, there are also drum screens, magnet separators and several stations for manual sorting. The waste fractions of plastics, metals, aluminum and glass are sorted out. Plastics and metals are compacted in baling presses. However, the amount of recyclables in the incoming waste is very low, as they are already picked out by the informal sector in the transfer stations (Rifki, 2021). It can be assumed that the informal sector brings a large part of the recyclable materials back into the cycle by sorting them out. For Marrakech, only the estimated 2015 recycling rates for the region of Marrakech-Safi exist. Therefore, WR is categorized in stage 1. The estimated data is as follows: metals: 62 %, paper: 22 %, glass: n.a., composites: n.a., plastics: 27 %, e-waste: 9 %, C&D waste: 0 % (GIZ, 2019). E-waste is disposed on the landfill or not recycled appropriately (Rifki, 2021). For C&D waste, no specific data was available. Currently, organic waste is mainly landfilled, composted at home or used to feed animals. Ecomed, the operator of the CEV, plans to construct a composting unit to pre-treat the incoming waste before landfilling, for emission reduction (e.g., methane). Moreover, an RDF unit to produce alternative fuels, which could be sold to a cement plant located near the landfill (Rifki, 2021), is planned. A fermentation plant is not available in Marrakech.

3.7. Prevention and reuse

After the analysis of PR, the results show various stage attributions for each subcomponent. PR.1 and PR.6 are in stage 1 due to the fact that no concrete goals regarding waste avoidance (e.g., food waste) exist and the Zero Waste Index (ZWI) for Morocco is under 0.05, which is extremely low (Zaman and Swapan, 2016). The ZWI describes the substitution potential of virgin material by secondary resources through recycling and recovery. Such a low ZWI means that only small amounts of virgin material are substituted. PR.1 was also considered to be partly in stage 3 because, based on Law 77-15 and Decree no 2-16-174, Morocco banned the manufacturing, trade and sale of plastic bags.

Repair, especially in African countries, is a very widespread practice (Rademaekers et al., 2020). The use of repair services instead of rebuying, especially for electronic products, furniture and textiles, is common in Marrakech as well as the use of spare parts. In Morocco, there are several spare parts online markets (especially for cars), like moulpieces.ma, monauto.ma, mister-auto.ma, etc. In 2022, a new website named Okato will be launched for the selling of general second-hand spare parts in Morocco (Okato, 2021). Besides repair, carpooling is also offered by the carpool service in Morocco (Pip Pip Yalah), which is also usable in Marrakech; however, a specific car-sharing system could not be found for Marrakech. Based on these results, PR.2 is attributed to stage 2, and partly to stage 3 and stage 4.

In Morocco, there are no mandatory deposit systems for products (e.g., packaging and batteries). A voluntary deposit system for PET bottles is provided by Marjan and Carrefour, which are supermarket chains. Marjan, for instance, introduced a deposit system for plastic bottles in different supermarkets in 2021 and plans to expand it in future due to good customer feedback (seariousbusiness.com, 2021). Due to an existing eco-tax on plastic products, some companies in Morocco considered the recyclability of their products in the product design phase (GIZ, 2019; WWF, 2019). There are companies in Marrakech that are taking into consideration end-of-life (EoL) issues in their processes, such as the packaging manufacturer UCC Paul Lagache and tea producer Siti Tea. These examples show that a basic awareness concerning waste and EoL issues is present in the context of companies. Subsequently, PR.3 is categorized mainly in stage 2. Regarding PR.4 (attributed to stage 2), one example was found showing a pioneer company considering issues of improving its waste prevention and disposal. Clubmed, a hotel chain, which also has hotels in Marrakech, conducted a study regarding food waste generation in their hotels and proposed measures to reduce the generated food waste (Bouvet, 2015).

For Morocco, the average waste generation rate per day per capita is

very low, with 0.76 kg for urban population and 0.30 kg for rural population (Diaco et al., 2020), compared to the rest of the world (Kaza et al., 2018). But for Marrakech, the daily waste generation rate per capita for 2015 was 1.12 kg, calculated based on the official numbers stated in Section 2.2. This rate corresponds to stage 3. Due to the fact that official numbers are not available, the waste generation rate does not reflect the current state; therefore, the average waste generation rate for Morocco is used for the stage categorization. However, the waste generation rate in Marrakech has to be critically observed to prevent the kind of growth that occurs in highly industrialized countries (Kaza et al., 2018).

3.8. Overall analysis results

The analysis results show the varying classification of the stages. ER and WR are both classified in stage 1. For WR, a slight development towards the next stage can be assumed due to the planned activities. CT and PR are mainly in stage 2, but also assigned to stage 1 (CT.4, CT.5, PR.1 and PR.6). For CT and PR, more effort to achieve higher stages can be seen in the results. According to the WMS-DSC results, G, SM and WD

Table 4
Short overview of the 33 measures to promote a circular economy in Marrakech (Morocco).

Recommendations for action			Level of application				State of priority		Precondition(s)
Cluster	Measure coding	Measure title	National	Regional	Municipal	Company	Essential	Relevant	
A	M1	Prescribe a mandatory separate collection of waste from households and businesses by law	x				x		
	M2	Introduce separate collection at municipal level			x		x		**M1**
	M3	Introduce decentralized drop-off bins for other types of residual wastes			x			x	
	M4	Increase the collection rate in rural areas and introduce its recording			x		x	x	
	M5	Increase the efficiency of transfer stations		x	x			x	
	M6	Standardize waste related data collection procedures	x	x	x		x	x	
B	M7.1	Enhance the regulatory WM framework concerning CE aspects	x				x	x	
	M7.2	Include the 5-stage waste hierarchy in the waste law	x				x		
	M7.3	Include the extended producer responsibility in the waste law	x				x		
	M8	Prescribe a mandatory systematic pretreatment for wastes before disposal	x				x		
	M9	Extend WM laws, plans and concepts at the regional and municipal levels concerning CE aspects		x	x		x		
	M10	Set and review waste targets	x	x	x			x	
	M11	Ratify other WM related international agreements	x					x	
	M12	Update the waste nomenclature	x					x	
	M13	Introduce a state-approved certification for WM companies	x					x	
	M14	Define emission limits for landfills and quality standards for secondary materials	x				x		
	M15	Implement clear and uniform collection, disposal and recycling rates	x				x		
	M16	Improve working conditions for the informal sector		x	x			x	
	M17	Increase transparency of trading structures for wastes and recyclables	x					x	
	M18	Offer insurances against caused environmental damages for companies				x		x	
	M19	Determine sites for a safe disposal of disaster waste		x	x			x	
C	M20	Install a composting unit in the CEV and increase its treatment capacities		x	x		x		
	M21	Install a leachate treatment process in the CEV		x	x			x	
	M22	Prepare favorable conditions for future sale of compost	x		x			x	**M2 & M20**
	M23	Enhance quality and quantity of sorted recyclables for high quality recycling			x	x		x	**M2, M5 & M14**
	M24	Strengthen and digitize the secondary resource market	x	x		x		x	
	M25	Provide a budget to promote WM and CE activities	x	x	x		x		
	M26	Intensify the integration of WM and CE aspects in companies and their company evaluation				x		x	
	M27	Integrate construction and demolition waste recycling in the WMS	x		x	x		x	
	M28	Incorporate a recycling center for e-waste in the WMS		x	x			x	
D	M29	Establish stakeholder platforms to foster exchange regarding CE	x	x	x	x		x	
	M30	Integrate WM and CE aspects in educational programs of schools		x	x			x	
	M31	Promote interdisciplinary research in WM and CE projects	x	x				x	
	M32	Increase cooperation between universities, WM and recycling companies	x	x	x	x		x	
	M33	Launch programs to train specialized personnel for the waste and recycling sector		x	x			x	

can be classified in stages 2 and 3 with a stronger trend towards stage 4.

3.9. Recommendations for action

Next, recommendations for actions are presented, which were identified based on the analysis results and the stage attributions. Due to the existing big distance to stage 5 for all components, the aim of the determined recommendations will, depending on the component, concentrate on specific stages to achieve a practical outcome. For example, for WR, it is important to get out of stage 1 first. For CT and WD, the goal should be to get every subcomponent at least to stage 3.

Finally, based on the results, 33 measures (Table 4) were derived to promote actions that enhances CE development in Marrakech and higher political levels, including the region of Marrakech-Safi and Morocco. The identified measures were summarized into four thematic clusters:

Cluster A: Increase collection rate and separate collection of waste.
Cluster B: Improve control, regulation, monitoring and assessment.
Cluster C: Promote closing the loop in Marrakech.
Cluster D: Encourage cooperation between research, companies and society.

Table 4 gives a short overview of the clusters, including the level of application, the states of priority and the preconditions for implementation. Twenty measures directly target the city of Marrakech, while 20, 16, and 7 target the national, regional, and company levels, respectively. Of all the measures, 13 are essential measures, meaning that they are fundamental to achieving stage 5, whereas 25 are considered as relevant. Some measures contain both essential and relevant aspects, such as M4, M6 and M7.1. The detailed descriptions of the measures are available in the supplements (S2).

These measures could be incorporated into action plans and development programs of the city of Marrakech or at higher levels. Development corporations could use these measures as basis for developing concrete projects. If the recommended actions are successfully implemented, apart from ER, all other components would be at least in stage 2. Therefore, CT, WD and WR would then be categorized in stages 2 and 3 and G, SM and PR in 2 to 4, which in turn would be a good basis for attaining CE in Marrakech.

4. Conclusion

Concerning WM, Marrakech is in a transition phase due to the implementation of measures at the CEV plant and the planning of a new Ecocenter to recycle waste. Besides, several other measures to improve waste collection and disposal are planned, such as investments to increase collection efficiency and the opening of a controlled landfill. However, there are still major deficits in the context of recycling, waste segregation and the consideration of other waste streams, such as C&D waste. A transition to a CE requires the implementation of key fundamentals (e.g., key measures in Table 4) at the municipal and higher levels; simultaneous implementation may be required. This transition can take several years to decades. The existing strengths of the city, such as the low waste generation rate, can be a good motivator to achieve a CE society as well as the 33 derived recommendations for action. The results allow a better understanding of the interdependencies between different WM activities. Furthermore, it is also possible to determine the necessity and order of implementation of certain measures, due to the identification of CE requirements (milestones) and existing dependencies between the system components and, thus, the measures.

Moreover, other municipalities of Morocco as well as municipalities of other GS countries with similar conditions can benefit from these recommendations for action, as some of them are very generally described and, therefore, universally valid. In the case of an analysis of another Moroccan municipality, the analysis using the WMS-DSC is simplified because this publication has already generated an analysis basis for aspects relevant at the national level (e.g., governance aspects). Nevertheless, it remains important for future analyses to check whether the analysis results are still valid or changed, for example, due to a further development or change of the system.

The case study showed that it is possible to make stage classifications through the WMS-DSC even when some data and information are lacking. The case study validated the WMS-DSC and showed that the concept can be used to perform an in-depth analysis with a benchmarking tool for cities in the Global South. In addition, it shows that through the specific definition of the individual stages and the existing stage descriptions, improvement measures can be derived in a simplified manner. One further advantage is that it does not analyze the individual WMS components independently but considers the system as a whole, including their interconnections. This makes it possible to identify measures that are interdependent. Such dependencies must be clearly identified before measure implementation to reduce potential implementation problems. These are decisive advantages over other methods. With the clear stage descriptions, especially for the higher stages (4 and 5), the WMS-DSC can have a beneficial effect on the promotion of the CE transition due to the fact that the visions are more imaginable.

While performing the analysis, some weaknesses of the approach were identified. As mentioned in Campitelli et al. (2022), the concept offers room for interpretation during the classification process, but it can be overcome by justifying the classifications in the result sheet (see S1). Due to the complexity of the WMS, not all possible interconnections are visualized in the concept, which could be a challenge if potential users with no or little WM knowledge use this approach to determine measures and identify possible interdependencies. Therefore, it must be considered that if the concept is used for cities of the Global South, certain knowledge regarding the WMS must be available.

The case study validated the WMS-DSC and demonstrated that this holistic approach, which is unique so far, adds value to WMS analysis in cities of the Global South.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

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Appendix A. Supplementary material

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References

Allesch, A., Brunner, P.H., 2014. Assessment methods for solid waste management: A literature review: [Review Article]. Waste Manage. Res. 32 (6), 461–473.

Bouvet, E., 2015. Etude gaspillage alimentaire au club med, 41 pp. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiozvuKuufxAhWVhv0HHeZSB-YQFnoECCUQAA&url=http%3A%2F%2Fdeveloppementdurable.clubmed%2Fwp-content%2Fuploads%2F2015%2F12%2FFR-Etude-gaspillage-alimentaire.pdf&usg=AOvVaw2R2Fg3zZZFeEHdJt3W6qvE. Accessed 16 July 2021.

Campitelli, A., Kannengießer, J., Schebek, L., 2022. Approach to Assess the Performance of Waste Management Systems towards a Circular Economy: Waste Management System Development Stage Concept (WMS-DSC). MethodsX 9, 101634.

Campitelli, A., Schebek, L., 2020. How is the performance of waste management systems assessed globally? J. Clean. Prod. 272, 122986.

C. Chance DÉCHETS La société marocaine en ordre dispersé contre la prolifération des déchets: CAS D'ÉTUDE MAROC 2020, 23 pp 2021 2020 Accessed 30 August.

Commission, E., 2019. The European Green Deal. COM(2019) 640 final. Brussels 24, pp. Accessed 28 December 2021.

European Commission, 2020. A new Circular Economy Action Plan: For a cleaner and more competitive Europe. COM(2020) 98 final, Brussels.

Diaco, M., Alami Merrouni, M., Bougarrani, S., Koehler, J., Hemkhaus, M., Ahlers, J., Desmond, P., Van Hummelen, S., McGovern, M., 2020. Circular Economy in Africa-EU Cooperation: Country Report Morocco. Trinomics B.V. ACEN, adelphi Consult GmbH and Cambridge Econometrics Ltd, p. 118 pp.. Accessed 15 July 2021.

EcoActu De la gestion des déchets vers un modèle marocain d'économie circulaire https://www.ecoactu.ma/de-la-gestion-des-dechets-vers-un-modele-marocain-deconomie-circulaire/ 2019 Accessed 13 January 2022.

Fatimah, Y.A., Govindan, K., Murniningsih, R., Setiawan, A., 2020. Industry 4.0 based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: A case study of Indonesia. J. Cleaner Prod. 269, 122263.

Ferronato, N., Torretta, V., 2019. Waste Mismanagement in Developing Countries: A Review of Global Issues. Int. J. Environ. Res. Public Health 16 (6), 1060.

Filho, W.L., Brandli, L., Moora, H., Kruopiene, J., Stenmarck, A., 2016. Benchmarking approaches and methods in the field of urban waste management. J. Cleaner Prod. 112, 4377–4386.

GIZ, 2019. Stratégie Nationale de Réduction et de Valorisation des Déchets (SNRVD), 250 pp. https://siredd.environnement.gov.ma/BeniMellal-Khenifra/Content/images/documents/Liens/ETUDE%20SNRVD%20-%2016-04-2019%20VF.pdf. Accessed 12 April 2021.

Haut-Commissariat au plan, 2012. Nomenclature Marocaine d'activites: NMA 2010, 51 pp. Accessed 3 September 2021.

HCP, 2014. Morocco Population Census - Marrakesh.

Independent Evaluation Group, 2017. Toward a Clean World for All: An IEG Evaluation of the World Bank Group's Support to Pollution Management. Report, Washington, D.C.

S. Kaza L.C. Yao P. Bhada-Tata F. Van Woerden What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 2018 Washington, DC: World Bank.

Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232.

Korhonen, J., Nuur, C., Feldmann, A., Birkie, S.E., 2018. Circular economy as an essentially contested concept. J. Cleaner Prod. 175, 544–552.

Lerpiniere, D., Wilson, D.C., Velis, V., Evans, B., Voss, H., Moodley, K., 2014. A Review of International Development Co-operation in Solid Waste Management: A report from the ISWA Task Force on Globalisation and Waste Management. Vienna 48, pp. Accessed 24 May 2020.

Ma, J., Hipel, K.W., 2016. Exploring social dimensions of municipal solid waste management around the globe - A systematic literature review. Waste Manage. 56, 3–12.

mapecology, 2020. Marrakech: La gestion des déchets confiée à l'Etablissement « Grand Marrakech » [Marrakech: Waste management entrusted to the Establishment "Grand Marrakech"]. http://mapecology.ma/slider/marrakech-gestion-dechets-confiee-a-letablissement-grand-marrakech/. Accessed 24 January 2022.

Royaume Du Maroc, 2006. Loi n°28-00 relative à la gestion des déchets et à leur élimination: loi 28-00, 17 pp.

Marshall, R.E., Farahbakhsh, K., 2013. Systems approaches to integrated solid waste management in developing countries. Waste Manage. 33 (4), 988–1003.

MEF, 2020. La Loi n°46-18 relative aux contrats de Partenariat Public-Privé adoptée par la Chambre des Représentants: 14/01/2020. hhttps://www.finances.gov.ma/fr/Pages/detail-actualite.aspx?fiche=4689. Accessed 1 February 2022.

Monnerjahn, M., 2019. There is much to do in Morocco's waste management sector [In Marokkos Abfallwirtschaft gibt es viel zu tun]. sector report. https://www.gtai.de/de/trade/marokko/branchen/in-marokkos-abfallwirtschaft-gibt-es-viel-zu-tun-204428. Accessed 22 March 2022.

Morocco-export.com, 2019. Waste: new conditions for import and export. Morocco-export.com, September 10.

MTEDD, 2022. Les missions [our missions]. https://www.environnement.gov.ma/fr/departement-de-l-environnement/2015-03-05-11-53-51/missions. Accessed 24 January 2022.

OKATO, 2021. 1er site d'annonces de pièces détachées d'occasion au Maroc. Accessed 13 January 2022. https://okato.ma/pourquoi-choisir-la-piece-auto-doccasion-au-maroc/.

Ouchagour, L., 2021. Marrakech will soon have a new Ecocenter.[Marrakech se dotera bientôt d'un nouvel Ecocentre]. https://aujourdhui.ma/economie/marrakech-se-dotera-bientot-dun-nouvel-ecocentre?unapproved=49212&moderation-hash=048260d2ac062e27a7733e964b5be205#comment-49212. Accessed 19 July 2021.

Ouchen, A., 2018. Waste management in the city of Marrakech: strategy, opportunities and constraints.: [La gestion des déchets au niveau de la ville de Marrakech: stratégie, opportunités et contraintes.]. AfriWaste Workshop, 7 November 2018, Marrakech, Morocco.

Pfaff-Simoneit, W., 2012. Development of a sectoral approach for the establishment of sustainable waste management systems in developing countries in the context of climate change and resource scarcity: [Entwicklung eines sektoralen Ansatzes zum Aufbau von nachhaltigen Abfallwirtschaftssystemen in Entwicklungsländern vor dem Hintergrund von Klimawandel und Ressourcenverknappung]. [Dissertation], Rostock, 249 pp.

Rademaekers, K., Smit, T., Artola, I., Koehler, J., Hemkhaus, M., Ahlers, J., van Hummelen, S., Chewpreecha, U., Smith, A. & McGovern, M., 2020. Circular economy in Africa-EU cooperation: Continental report. Trinomics B.V., Tomorrow Matters Now Ltd., adelphi Consult GmbH and Cambridge Econometrics Ltd., Luxembourg, 1147 pp. Accessed 14 October 2021.

Rand, T., Haukohl, J., Marxen, U., 2000. Municipal Solid Waste Incineration: A Decision Maker's Guide, Washington, D.C., 18 pp. Accessed 9 May 2019.

Rifki, R., 2021. Interview regarding the valorisation plant and landfill CEV in Marrakech, online.

Saadoun, L., Campitelli, A., Kannengiesser, J., Stanojkovski, D., Fels, El Alaoui El, Abdelhafid, Mandi L., Ouazzani, N., 2021. Potential of medium chain fatty acids production from municipal solid waste leachate: Effect of age and external electron donors. Waste Manage. (New York N.Y.) 120, 503–512.

L. Salamy Bebila Mouvement transfrontière des déchets: Importation et réutilisation des déchets au Maroc 2020 Mediaterre.org, August 18.

N. Schneider Between Promise and Skepticism The Global South and Our Role as Engaged Intellectuals The Global South 11 2 2017 18.

seariousbusiness.com, 2021. Morocco - MOSSUP. https://www.seariousbusiness.com/morocco. Accessed 1 February 2022.

SIREDD, 2022a. Accueil / Indicateurs - Environnement Socio Human - Dechet. Accessed 26 January 2022. https://siredd.environnement.gov.ma/Marrakech-Safi/indicateur#.

SIREDD, 2022b. Direction régionale de l'environnement. Accessed 24 January 2022. https://siredd.environnement.gov.ma/Marrakech-Safi/Home/observatoire.

UN, 2014. World urbanization prospects: The 2014 revision - highlights. United Nations, s.l., 32 pp.

UN, 2018. Annual Population of Urban Agglomerations with 300,000 or more in 2018 (thousands): World Urbanization Prospects 2018. Data Query.

A. van de Klundert J. Anschütz Integrated Sustainable Waste Management - the Concept.: Tools for Decision-makers. Experiences from the Urban Waste Expertise Programme 2001 WASTE, Gouda, Niederlande 46 pp. Accessed 20 March 2018.

Whiteman, A., Webster, M., Wilson, D.C., 2021. The nine development bands A conceptual framework and global theory for waste and development. Waste Manag Res 39 (10), 1218–1236.

Wilson, D.C., 2007. Development drivers for waste management. Waste Manage Res. 25 (3), 198–207.

Wilson, D.C., Rodic, L., Scheinberg, A., Velis, C.A., Alabaster, G., 2012. Comparative analysis of solid waste management in 20 cities. Waste Manage Res. 30 (3), 237–254.

World Bank Data for Morocco and Cote d'Ivoire 2020 https://data.worldbank.org/?locations=MA-CI.

WWF, 2019. Stop the flood of plastic.: A guide for policy-makers in Morocco. https://wwfeu.awsassets.panda.org/downloads/05062019_wwf_marocco_guidebook.pdf. Accessed 1 February 2022.

A. Yahya Marrakech adopte un système de gestion intégrée du service de propreté [Marrakech adopts an integrated management system of the cleaning service 2021 https://www.mapnews.ma/fr/actualites/r%C3%A9gional/marrakech-adopte-un-syst%C3%A8me-de-gestion-int%C3%A9gr%C3%A9e-du-service-de-propret%C3%A9.

Zaman, A.U., Swapan, M.S.H., 2016. Performance evaluation and benchmarking of global waste management systems. Resour Conserv Recycl 114, 32–41.

Zhang, X.Q., 2016. The trends, promises and challenges of urbanisation in the world. Habitat. Int. 54, 241–252.

Zurbrügg, C., Caniato, M., Vaccari, M., 2014. How Assessment Methods Can Support Solid Waste Management in Developing Countries-A Critical Review. Sustainability 6 (2), 545–570.