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the metabolic periphery

towards socially, economically and ecologically productive operational landscapes in the periphery of Madrid

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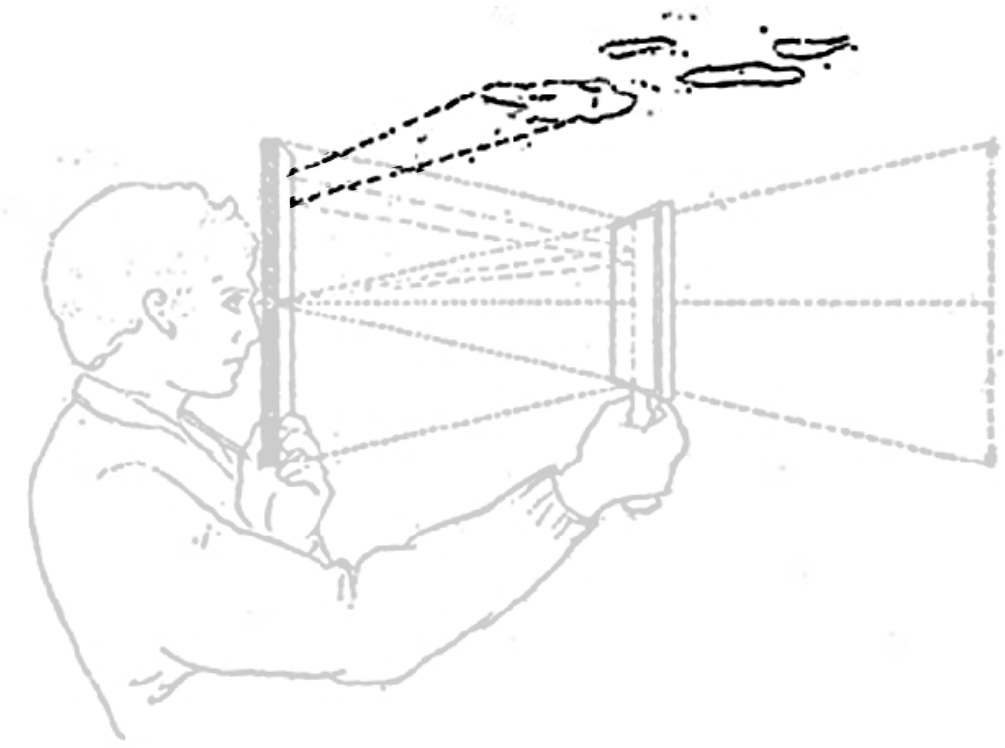
abstract

Contemporary cities typically employ a linear metabolic model which relies on peripheral areas to support their growth and operation, often externalising waste and degradation to economically and ecologically vulnerable areas. Posing the hypothetical question, 'What if the existing metabolic processes of extraction, production and disposal in Madrid's periphery could be rethought, and a socially, economically and ecologically productive process could be instated for peripheral communities?', this paper constructs a theoretical framework with which to understand systems of waste and inequality embedded in the city's growth and operation, and analyses the historical patterns of growth which proliferated them. Following this understanding, contemporary problematic symptoms emerging from these patterns are identified, and a set of good practices is compiled which may effectively address them. This research takes a critical stance on the tabula rasa form of urban redevelopment commonly employed in Madrid and posits that an alternative model of urban development should be estalished, one which embraces plurality and uses existing built fabric and social, ecological and economic processes as a starting point.

periphery, urban metabolism, unequal exchange, drosscapes, operational landscapes, urban growth

while performing the necessary operative functions of the city's metabolism - such as material extraction, processing, and waste disposal - operational landscapes are typically relegated to the territorial and global periphery, intangible in one's typical experience of the city



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i. introduction

Contemporary cities are defined by a globalized metabolic process in which centralised urban areas, those zones of agglomeration and accumulation, are reliant on peripheral zones of extraction, production and disposal, covering even the most remote regions of the planet (Ibañez & Katsikis, 2014). Those zones of extraction, production and disposal, which facilitate the linear metabolisms of contemporary cities may be defined as **operational landscapes**. Although urban centres are intrinsically tied to such landscapes, as their physical materiality is derived from them, they are intangible in the average experience of the city. This is because on a planetary scale they are scattered in the **global hinterland**, detached and out of sight from the urban core. On a regional scale - within the city and its surrounding territory - operational landscapes are typically located on the **periphery**, a zone in-between the centre and the hinterland, where operational processes take place on a smaller scale.

This system is framed within the **Capitalocene**, an era in which the earth itself has been commodified, and in which nature is organised through capital-generating processes (Moore, 2015). Peripheral operational landscapes supply urban centres through a complex network of infrastructure and human labour. Cities are reliant on these operational landscapes, located in the global hinterland, to supply them with the physical material that forms them. As natural landscapes are transformed into raw materials, which then become commodified products once extracted, the rift between the consumer and the process of production deepens. However, materials should not be understood as fixed commodities, but as objects that are continuous from the landscapes they originate from, and although these landscapes may seem distant, urban centres and peripheral operational landscapes are socially, ecologically, economically and politically linked territories (Ibañez & Katsikis, 2014).

However, these two territories do not mutually benefit from their exchange of resources, leading to an **unequal exchange** between the two. Jane Hutton emphasises this point in 'Reciprocal Landscapes: Stories of Material Movement', where she discusses the relationship between urban centres and the operational territories that feed them (Hutton, 2019). While cities benefit from the accumulation of capital, operational landscapes often suffer from contamination and systemic **underdevelopment**. Furthermore, operational landscapes also suffer economically as produced, finished products tend to be priced disproportionally higher than raw materials, and extractive economies decrease in power over time, while core industrial economies increase in power (Hutton, 2019). In 'Unless: The

figure 1 (page 5)
an edited illustration of Brunneleschi's perspective experiment. while the sky and clouds above the human figure supply the light for the scene, they are out of sight in an orthographic persepctive. Similarly, operational landscapes that supply resources for the city, they are out of sight in the object-oriented viewing of the city (Lancia, 2008).

operational landscapes
sites of material extraction, waste disposal, production, processing and logistics, which perform operative tasks for the city.

periphery
the periphery is understood as the immediate urban edge, a transitional zone, often hosting operational landscapes and low-cost housing. By contrast, the hinterland refers to the broader territorial and global landscapes that support the city's metabolism - often distant, yet strongly tied to urban processes.

capitalocene
the Capitalocene frames capitalism as the central force behind humanity's organisation of nature, exploring its associated negative implications. Within the Capitalocene, cities are framed as dense agglomerations of capital, formed through material commodities extracted from the earth.

Seagram Building Construction Ecology', Kiel Moe discusses similar issues of unequal exchange, where he draws poignant examples of the unequal exchanges between an urban centre of power and the operational landscapes that supply it by describing the construction ecology of the Seagram Building. He frames the Seagram building as a manifestation of capitalist ideals; a representation of wealth and power, situated in the centre of Midtown Manhattan; "a trophy". This description is then juxtaposed with the "atrophy" it caused in the operational landscapes that supplied it, such as the Chuquicamata copper mine in Chile, or a glass factory in the small town of Butler, Pennsylvania that went out of business shortly after the Seagram Building's construction, leading to social, ecological and economic degradation which disproportionally affected vulnerable members of society (Moe, 2021).

unequal exchange
while urban centres benefit from accumulation, peripheral operational landscapes suffer economically, ecologically and socially through the exchange performed with the centre.

While these systems of unequal exchange take place on a global scale - between urban centres and far-reaching operational landscapes in the global hinterland - a similar dynamic takes place within the city's territory, in regional and urban scales. Low-income and disadvantaged communities commonly reside in neighbourhoods in proximity to operational processes, which in the case of Madrid is not an accidental arrangement, but is strategically designed through the city's urban planning, discussed further in chapter two. A similar understanding of 'discard' is discussed in '**Discard Studies**: Wasting, Systems and Power', where Lepawsky and Liboiron argue for a framework where material waste is not the main object of study, instead investigating broader systems of waste and wasting. Their position is that political and economic systems of power preserve their position by discarding certain people, places and things.

> The broad and systematic approach to how some materials, practices, regions and people are valued and devalued, become disposable or dominant, is at the heart of discard studies. (Liboiron & Lepawsky, 2022)

underdevelopment
Stephen Bunker's Theory of Underdevelopment - extractive peripheral areas are structurally underdeveloped over time through the processes of extraction and unequal exchange. They typically become poorer over time, and they do not have the means to rehabilitate their environment, while wealth is concentrated in central urban agglomerations. (Bunker, 1985)

Through this understanding, the location of operational processes in the periphery, and the underdevelopment of communities in proximity to them is not accidental, but intentional, as power is maintained by the urban centre by marginalising unwanted processes and people.

drosscapes
vast, wasteful and wasting landscapes produced by urban areas.

Alan Berger offers a complementary lens with which to understand the unequal and wasteful metabolic processes of the contemporary city. In his book 'Drosscapes: Wasting Land in Urban America' he coined the term **drosscapes**, which refer to

wasteful and wasting landscapes that contribute towards and are created from the ecologically unsustainable metabolic models of cities (Berger, 2006). Drosscapes may be understood in a multitude of ways. They include urban landscapes which contribute to systems of waste, landscapes which are themselves wasted by inefficient urbanisation, and operational landscapes which enable the wasteful systems performed by urban regions. This paper later defines six drosscapes in Madrid's context, which are understood as contributing factors to the city's wasteful practices, or direct products of those practices.

The synthesis of the discussed literary sources establishes a theoretical framework through which the operational processes of the city – its ongoing metabolism and model of growth – may be understood critically. Wastefulness is not only understood through the generation of physical waste sent to landfills, but also through the misallocation of resources, underutilised potentials, and the proliferation of excessive infrastructures. It also emphasises the social, economic and ecological inequalities embedded within wasteful practices of operation and growth. While grounded in the case of Madrid, this interpretive lens may also be applied to other urban centres globally, where similar historical and contemporary patterns of waste and unequal exchange often recur.

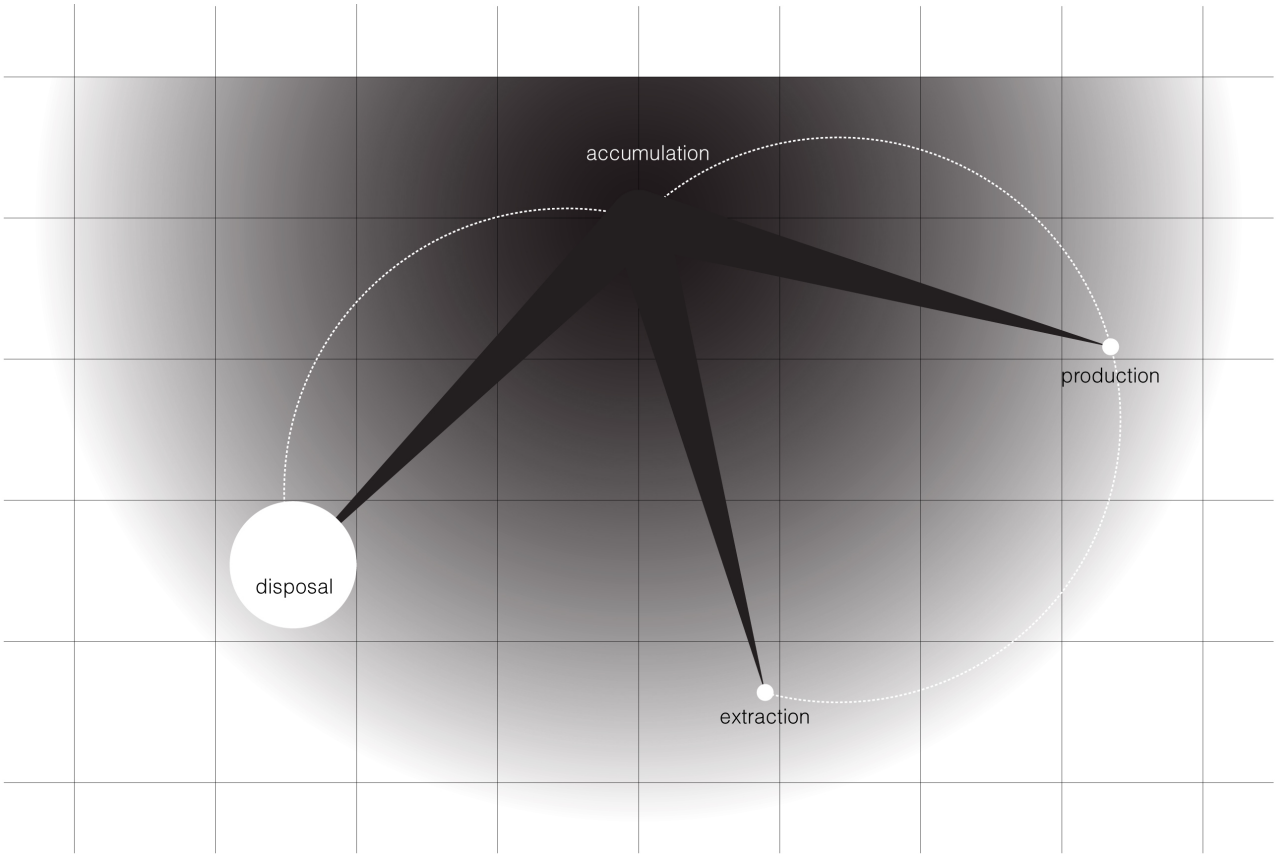
Wasteful and unequal **metabolic processes** are certainly evident in Madrid and can be traced onto the city's socio-spatial organisation. The city's operational landscapes which facilitate its urban metabolism - those zones of extraction, production and disposal - are relegated to its vast periphery, particularly in the southeast. The location of operational landscapes here is rooted in geographic conditions and the historic and contemporary socio-economic landscape of the city. An invisible, but tangible line may be drawn from the northwest to the southeast of Madrid, which defines its social and economic inequality, underdevelopment and contamination, and has been termed the ***diagonal de la segregación*** , or the 'diagonal of segregation' (*Club de Debates Urbanos*, 2018).

> The southern districts are defined as isolated spaces, functionally specialised in housing heavy, harmful, unhealthy or dangerous industry, with severe environmental deficiencies, deficits in facilities of all kinds (transport, schools, health centres, green areas, cultural facilities...) and with the presence of large infrastructures that fracture it and degrade the living conditions of its inhabitants. The southern districts socially exemplify discrimination and an absolute dependence on centrality (*Club de Debates Urbanos*, 2018).

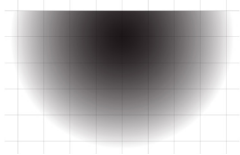
metabolic processes
refer both to the operative systems that sustain urban life - such as material extraction, production, logistics, and disposal - and to the transformation of landscapes, ecologies, and materials that are themselves metabolised by the city. Therefore, these processes enable urban growth while simultaneously altering, consuming, and depleting the territories that support them

diagonal de la segragacion
a diagonal line can be drawn from the northwest to the southeast of Madrid along which people are organised by wealth and opportunity, with the southeast being the most disadvantaged region of the city.

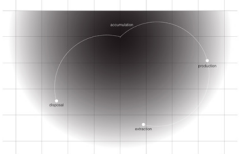
figure 2 (page 11)
theoretical framework diagram with visual references (author, 2024)

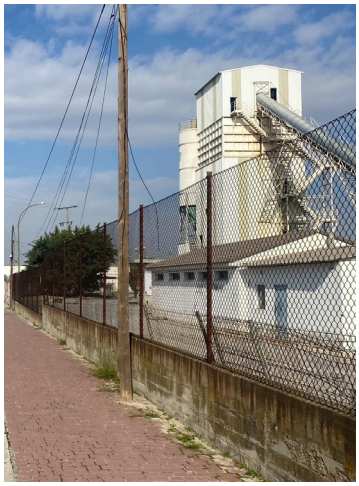


the contemporary city within the capitalocene

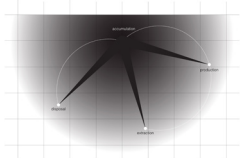


operational landscapes in the periphery

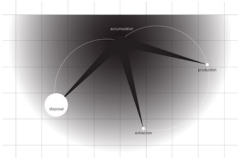


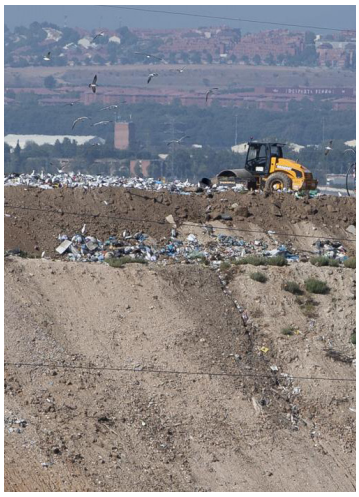


unequal exchange between the periphery and the centre



embedded wasteful practices





The role of the southeastern periphery as Madrid's back-end operational territory, performing the undesirable processes of the city's metabolic cycle, has contributed to its underdevelopment, and while the financially driven centre benefits from the operative performance of its periphery, the periphery suffers socially, economically and ecologically. This creates an unequal exchange within the city, where the wealthy, financialised centre benefits from a metabolic process that relies on systems of degradation in its periphery.

The re-evaluation of the city's metabolic processes, and their associated systems of waste and inequality is critical in the face of the massive urban transformations set to take place in Madrid's periphery. Projects such as the *Nuevo Norte* (a new financial district in a former railway area), the Madrid Metropolitan Forest (a proposed greenbelt wrapping around the city's periphery) and the large-scale, ongoing real estate developments in the south, will not only demand new infrastructure and a supply of extracted materials to facilitate their construction - but if executed poorly, they will contribute to the proliferation of drosscapes in the city. These large-scale projects, all located in Madrid's extremities, position the periphery as a critical zone in which significant change is set to take place. This region is therefore an opportunity zone, where a change in the metabolic processes associated with continued urban growth can be instated, moving away from wasteful practices of growth which will generate more drosscapes, degradation and inequality in peripheral areas.

figure 3
demolition of a concrete factory in Vicálvaro, replaced by housing (Robert Royal, 1998-2001).

Figure 3 depicts a former concrete factory in Vicálvaro (a district in the southeast of Madrid) being torn down, to be replaced by housing blocks similar to those in the foreground. In the image one can observe several wasteful practices commonly seen in Madrid's urban growth, and its embedded systems of wastefulness and unequal social, economic and ecological exchange:

1. During its operation, the factory represented a source of contamination for the communities living in proximity to it, while providing building materials which generated revenue for developments further upstream.
2. The demolition of the factory's physical fabric contributes to a wasteful, linear system of urban expansion. The demolished material was likely sent to a landfill or partially recycled, processes which require further infrastructures and operations.
3. The continued reliance on extractive and productive processes which will be required to construct the factory's replacement
4. The new construction itself, composed of commodified housing blocks, built with the intent to generate capital, but being socially, economically and ecologically unproductive for the community.

Through the process of the city's development, Madrid's periphery has been systematically devalued and discarded by the powers of the city. The southeastern periphery especially may be described as a patchwork of drosscapes. The region is filled with such sites, including operational landscapes, unused land, socially and ecologically unproductive developments, and areas which promote wasteful lifestyles. However, the term 'drosscapes' may also be interpreted to carry with it certain positive implications for the future of these sites, as it suggests that landscapes of dross may be 'scaped' or resurfaced to become productive. This research aims to conceptually resurface the dross in Madrid's periphery. As a place in flux, the periphery offers an opportunity area where a systematic change to the city's metabolism can take place, turning wasteful, contaminating landscapes at the less favourable end of an unequal exchange into socially and ecologically productive places.

ii. spatialisation of waste and inequality in madrid

Inequality in Madrid

The spatialisation of operational landscapes in Madrid has been determined greatly by the territory's geography. The terrain to the north is mountainous, while the south consists of lower ground, with the Manzanares River flowing downstream from north to south. Given this natural gradient, it seems logical that industrial processes have historically been concentrated towards the south, minimising the risk of contaminating the city's ground, water and air. This dichotomy between north and south has been maintained throughout Madrid's growth, as contaminating processes continue to be relocated further south. Socially and economically disadvantaged communities have also been systematically concentrated in the southern regions of the city, alongside contaminating processes.

Madrid's southern population is structurally disadvantaged through planning decisions made throughout the city's history. In the Castro Plan, the first major expansion of Madrid, Arganzuela - the new southern district - was designated as an industrial area mixed with housing for working-class people employed in the nearby factories, while expansions towards the north and east were designated for higher classes of people, with those districts also being better funded during construction (Vicente Albarrán, 2014). A map of average income levels per person in Madrid in 2022, using data retrieved from the INE (Instituto Nacional de Estadística) and visualised by the author, reveals a stark economic divide, with the southern portion of the city being significantly disadvantaged compared to the centre and the north (figure 4). This spatial arrangement highlights the direct relationship between geographic conditions, operational processes and socio-economic inequality. Madrid's urban landscape is deeply intertwined with these systemic disparities, which are embedded in the city's metabolic processes.

figure 4 (page 15)
Income per person in Madrid (Instituto Nacional de Estadica, 2022) paired with images of corresponding neighbourhoods (mixed authors).


el cañaveral

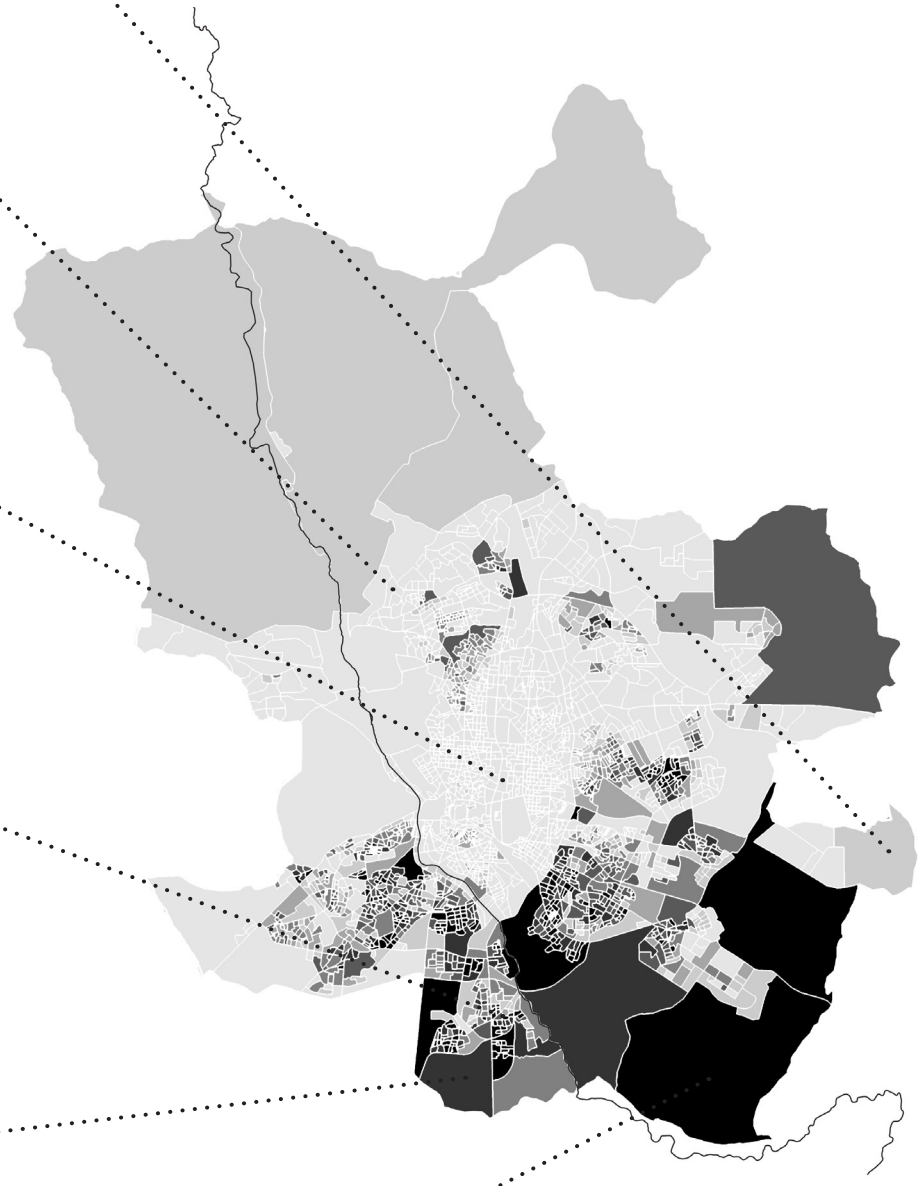

mirasierra


salamanca


san cristóbal


villaverde alto


cañada real



4.995 - 9.932
9.932 - 11.172
11.172 - 12.528
12.528 - 13.917
13.917 - 15.459
15.459 - 17.445
17.445 - 34.765

Coined by Alan Berger in his publication ‘Drosscapes: Wasting Land in Urban America’, the term ‘drosscapes’ refers to waste landscapes and spaces that are wasted within the urban environment (Berger, 2006). Six prevalent drosscapes were identified within the context of Madrid, which either directly contribute to wasteful systems of growth and operation in the city, or are a direct product of those systems. The six drosscapes mapped include landscapes of extraction and disposal, sprawling monofunctional industrial estates, monofunctional commodified housing districts, sprawling motorway infrastructure, abandoned infrastructural or operational fabric, and abandoned or partially constructed areas of speculative urban expansion. However, drosscapes in Madrid are certainly not limited to these six categories.

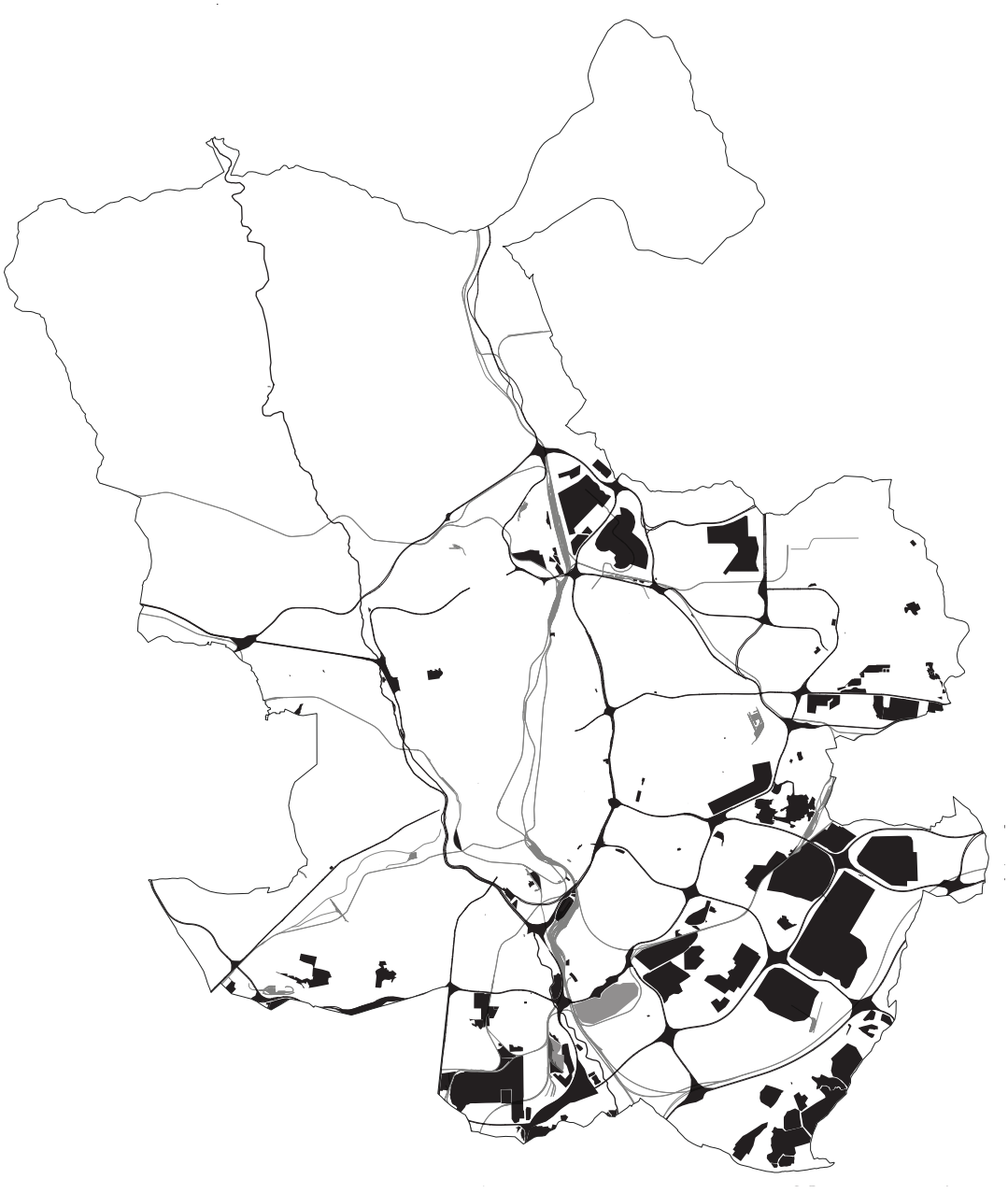


figure 5
combined dross-capes in Madrid (author, 2024)

1. Landscapes of Extraction and Disposal

Sites of material extraction and disposal constitute the beginning and end of the city's linear metabolic process. The main extractive processes around the city include several gravel pits and concrete production plants, mainly around the southeast, stone quarries in the mountainous areas towards the north, and two large chemical mines operated by TOLSA in Vicálvaro and San Blas, two districts in the south of the city. The Valdemingomez landfill, on the southern edge of the city, is the largest handler of waste in Madrid, and includes capped and active landfills and waste recycling plants.

2. Sprawling Monofunctional Industrial Estates

Several large industrial estates are scattered around the city's periphery, and almost all operational processes that serve Madrid, such as logistics activities and various forms of production are sited in these areas. The spatial characteristics of these industrial estates are inherently wasteful, as they are isolated from the urban centre, leading them to be heavily reliant on motorway infrastructure. Their isolation also leaves them unable to synergise with other urban processes, and the potential for operational and social processes to mutually support one another is removed, while operational byproducts are largely untapped.

3. Monofunctional Commodified Housing Developments

There is a large volume of recently completed, ongoing and planned construction in Madrid's periphery, which are generally speculative endeavours aimed to turn a profit. These developments are very similar to one another, and they are isolated and sprawling, leaving their residents almost entirely reliant on the private vehicle as a primary form of transportation.

During my visit to Madrid, I encountered several of these new speculative developments. It appeared from observation that many of these projects are driven by a small group of private developers, namely Pryconsa, a leading developer in the housing market in Spain. My visit to El Cañaveral was especially impactful; El Cañaveral is a young administrative neighbourhood established in 2017, which forms part of the Vicálvaro district (Madrid City Council, 2017). With its construction beginning in 2013, the neighbourhood is composed entirely of new housing blocks, accessed by wide roads, sometimes having four lanes of traffic flowing in each direction (figures 10, 12). However, although the neighbourhood

has built an extensive road network to support it, it is largely devoid of human life, save the construction workers involved in the ongoing project.

Unfortunately, it seems as though the urban development model at El Cañaveral is the standard for much of the proposed suburban development in the south. A new district, called Los Cerros, is planned to be constructed on the southern edge of the city, in the Villa de Vallecas district. This new development is set to cover 4.7 million square metres and include over 14,000 new homes (Los Cerros, 2025). Images of the new development show large car-centric roads intersecting at large roundabouts, with housing blocks placed sparsely in between the roads. It is a vision for urban expansion which is consistent in Madrid's periphery, and present in newly constructed developments such as El Cañaveral. This spatial configuration is incredibly wasteful, utilising land carelessly, focusing on car-dependent infrastructure, and making use of large amounts of raw material for construction.

4. Partially Constructed Areas of Speculative Urban Expansion

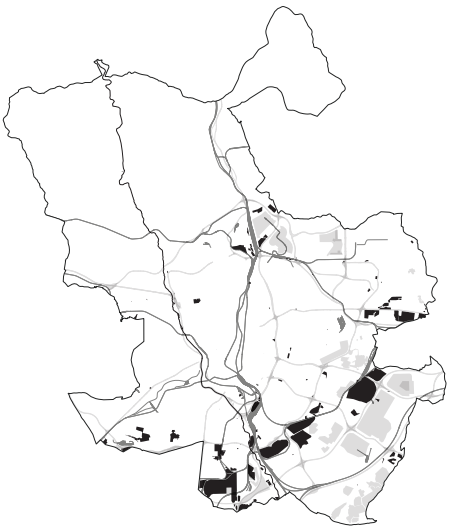
Amidst the sprawling landscape of speculative development are areas unsuccessful in their completion. There are several areas in Madrid's periphery which are partially constructed – where the roads, utility lines, and other infrastructures have been constructed but there are no buildings or people to make use of them. In the Villa de Vallecas district there is a particularly striking example of an unfinished speculative development. During my visit I was able to get a view over this large expanse of failed speculative development, by climbing the Almodovar hill and looking over towards the edge of the city (figure 9). This district was discussed in Christopher Marcinkoski's book 'The City that Never Was' which discusses similar failed urban developments in various parts of the world, which are a result of wasteful urbanisation fuelled by the financialization of our built and unbuilt environment (Marcinkoski, 2016).

5. Sprawling Motorway Infrastructures

Madrid is a concentrically organised city. While the M-30 highway defines the limits of the urban centre, other motorways are offset from it, such as the M-40 and M-50, defining further peripheral zones in the city. The motorway infrastructure in Madrid is dense, and since the concentric highways are connected perpendicularly to one another, the urban pockets in between them become pedestrian islands, segregated from the continuous urban fabric of the city. The highway intersections here are also vast and can occupy large parcels of land. These objects facilitate

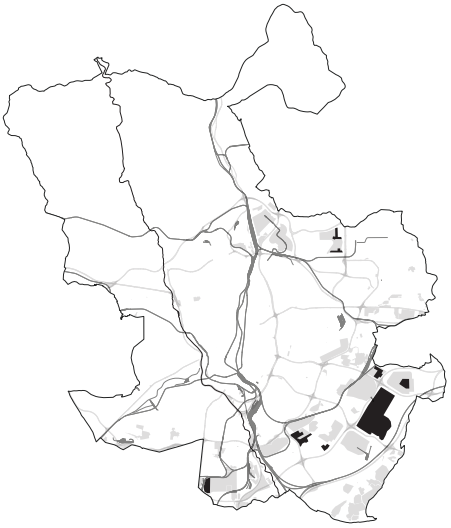
figure 6
drosscapes in Madrid
(author, 2024)

extraction and disposal sites

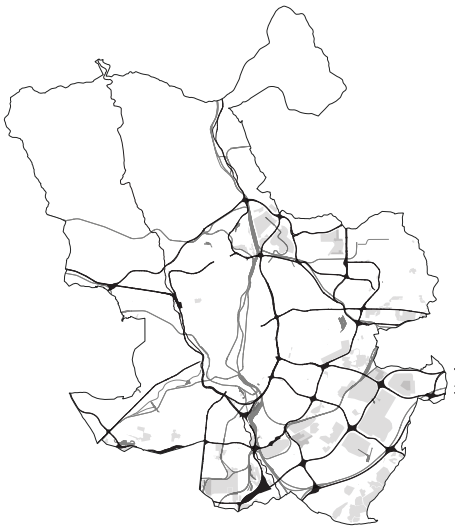


industrial estates

sprawling real estate developments



partly constructed developments



motorway infrastructure

operational leftovers

a wasteful form of transportation and prevent the land they occupy from being utilised more productively.

6. Infrastructural and Operational Leftovers

As areas within the city were continuously redefined, and de-operationalised at different points in their history, there are several industrial and infrastructural leftovers – built fabric which has been left in a state of decay. While these leftovers have unique spatial and material potentials, they are untapped and left abandoned (figure 11).

figure 7
consumer-centric car-scape in Vicálvaro (author, 2024).

figure 8
large amounts of waste are seen dumped on empty patches of land in Villaverde (author, 2024).

figure 9
unfinished urban
expansion project,
Villa de Vallecas
(author, 2024)

figure 10 (above)
recently constructed real estate development in El Cañaveral (author, 2024).

figure 11 (page 25)
former railway worker housing in Villaverde, constructed in the early 20th century, now left in a state of decay (author, 2024).


FREE
KNSE

figure 12 (page 26-27)
ongoing construction project at El Cañaveral (author, 2024).

figure 13
Alcalá de Henares landfill (Saint Bernard, 2019)

figure 14
Los Cerros development proposal (Ibosa Group)

iii. tracing waste and inequality through madrid's historic urban growth

Madrid's urban growth since industrialisation may be traced along a section of the city I define as the '**operational territory**'. This is a region of the city in which the Manzanares cuts through, north to south, and where the displacement of operational landscapes, and the continuous redefinition of urban-operational dynamics may be observed historically. By following the river downstream, one also follows streams of contamination, and the path along which disadvantaged communities and industrial activity have been discarded.

operational territory
defined further in chapter v. mappings (figures 21, 22).

The Ensanche de Madrid (also referred to as the Castro Plan), was the first major expansion outwards for the city. Commissioned in 1857 and executed from 1871, the plan established three new districts, to the city's north (Chamberi), the east (Salamanca and Retiro) and the south (Arganzuela) (Aparisi Laporta, 2004). The

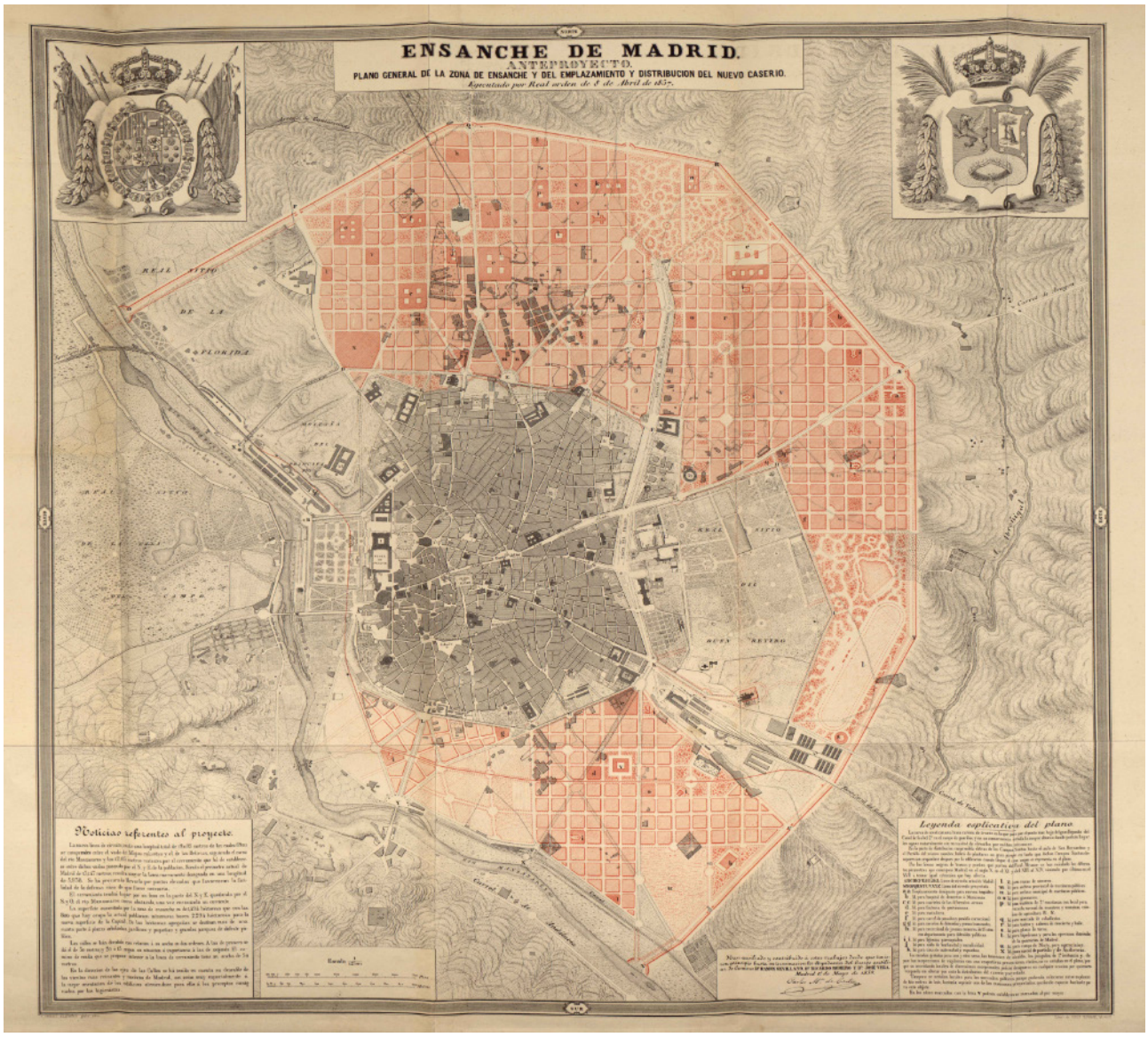


figure 15
plan of Madrid's expansion, 1861 (Carlos María de Castro, 1861).

Castro Plan set the stage for structural inequalities in the city's urban planning, as the three new districts were zoned to house people of different social classes, who were set to be segregated. The expansion towards the south (Arganzuela) was conceived as a district to house various industries and working-class people who worked at the nearby factories. Furthermore, during its development, the district was also allocated less funds than its counterparts, leading to its underdevelopment and personification as the "Madrilenian underworld" (Vicente Albarrán, 2014).

The development of industry in Madrid is strongly tied to the city's railway infrastructure, a quality which is highly apparent in Arganzuela. The neighbourhood had three major train stations at the time, built in the late 19th to early 20th century; the Mediodía station, now known as Atocha, the Delicias station and the Imperial station, the former two of which were mainly used for freight transportation. The presence of railway infrastructure led to several industries, workshops and factories emerging in the district during this period. Significant operational buildings in Arganzuela in the 19th century included the *Gasometro* (gas factory), the Standard Electric Factory and the *El Águila* brewery. Other operational buildings continued emerging into the early 20th century, such as the *Matadero* (slaughterhouse), and the Legazpi fruit and vegetable market, established in 1924 and 1935 respectively.

However, Arganzuela was not the only area performing much of Madrid's operational processes at the time, as Vallecas, a district just south of Arganzuela, which was an independent town until it was incorporated into the city in 1950, also had a rich industrial heritage, and was a key supplier of building material used in the 1871 expansion project. This is described in a book titled "*Historia de Madrid y de los pueblos de su provincia*" (History of Madrid and the Towns of its Province) , published in 1921 by Juan Ortega Rubio, who wrote that the land at Vallecas is "good for vegetables, cereals, olive groves and vineyards, with some livestock and game", and he stated that "industry remains advanced, as evidenced by a tannery, a textile factory, several ceramic and plaster factories, a briquette factory, an acid factory and a printing press…" (Ortega Rubio, 1921). The town therefore had relative success and prosperity during the late 19th to early 20th century due to its proximity to Madrid's urban centre, and its role in supplying products and building materials for the city (Fernández Montes, 2001).

Both the districts of Arganzuela and Vallecas underwent massive urban transformations in the second half of the 20th century. The de-industrialisation of urban centres was a trend in many major cities around the world at this time,

figure 16
Arganzuela, a formerly mixed urban and industrial neighbourhood (Paisajes Españoles, 1961).

as industries generally moved from the centre to the periphery, leaving behind several spatial leftovers in central areas of the city. These former industrial sites left a void which garnered significant speculative interest from local governments and real estate developers. During the deindustrialisation of Madrid, industries moved out of relatively central districts like Arganzuela and Vallecas, to monofunctional areas designed specifically to house industry, such as the industrial estate at Villaverde, a district in the southern edge of Madrid. Although the relocation of industry was done with the stated intention of improving efficiency and cleaning the centre from potentially contaminating processes, it had the simultaneous effect of inhibiting the survival of certain industries which could have fit well within a mixed urban fabric, as their operation sometimes overlaps with other urban or social processes found in more central and compact areas of the city.

Arganzuela was home to several industries, many of which dated back to the late 19th century, but by the end of the 1970s, the industrial fabric which previously existed alongside urban functions had been almost entirely abandoned or demolished and replaced by residential developments, and by the end of the 20th century, industry had been almost entirely relocated to new monofunctional

industrial estates. Concurrent to the de-operationalisation of the city centre was an economic crisis which meant that many companies that did not have the means to relocate themselves were forced to shut down. In the core districts of the city (such as Centro, Salamanca and Chamberí) there were compact, labour intensive industries such as textile and graphic arts industries, while slightly outside the centre (in neighbourhoods such as Retiro, Tetuán, Chamartín and Arganzuela) there were more concentrated and intense productive processes taking place, such as chemical, wood, electrical and metallurgy industries (Fidel, 2008).

The large brick factories that dominated the landscape of Vallecas in the early 20th century were eventually demolished and replaced by housing blocks, with the district being mainly zoned for residential use instead. The Valderribas brick factory had once occupied a massive land area in Vallecas, but was replaced by socially unproductive housing block commodities in the 1980s, leaving little of its historic industrial fabric. While the district was a prosperous industrial hub at its peak, it experienced economic decline in the second half of the 20th century due to its de-industrialisation and the removal of its productive capacity, and it is now one of the poorest districts of the city (Plaza, 2020).

In his work "*Vaciado industrial y nuevo paisaje urbano de Madrid*", (Industrial Emptying and New Urban Landscape in Madrid), Carlos Pardo Abad states that the cessation of industrial activity in the urban centre was due to a combination of factors, including a response to urban planning, and economic and speculative motivations (Pardo Abad, 2006). Although the freeing up of land in the centre allowed speculative development to take place, and an intensification of urban functions, it also led to gentrification, and the expulsion of certain communities that were also linked to former industries. The 1946 General Urban Development Plan

figure 17
site of the Valderribas brick factory, now occupied by housing blocks.

of Madrid was especially effective in the de-industrialisation of the city's centre. This plan zoned Villaverde to become an industrial hub, which according to the document was necessary for the constitution of a "true city". During the late 20th century, the industrial area towards the south of the district grew rapidly, alongside other residential neighbourhoods around it, including the new Villaverde Medio and the expansion of Villaverde Alto. However, starting in 1970, industrial activity in Madrid began to decline, and Villaverde continues to suffer the consequences of the downturn in the industrial activity it was once immersed in. It is now one of the poorest districts of the city, and its industrial estate is a hotbed of poverty and criminality.

figure 18 (page 35)
urban - operational development in Madrid, abstracted into temporal mappings (author, 2025).

8 introduction

x spatialisation of waste and inequality in madrid

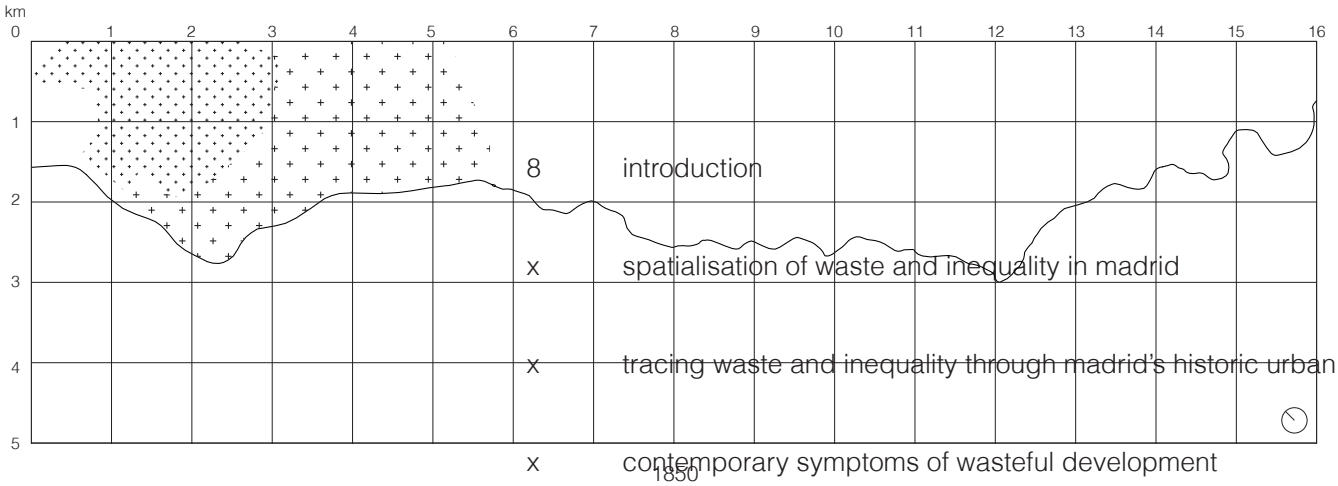
x tracing waste and inequality through madrid's historic urban growth

x contemporary symptoms of wasteful development

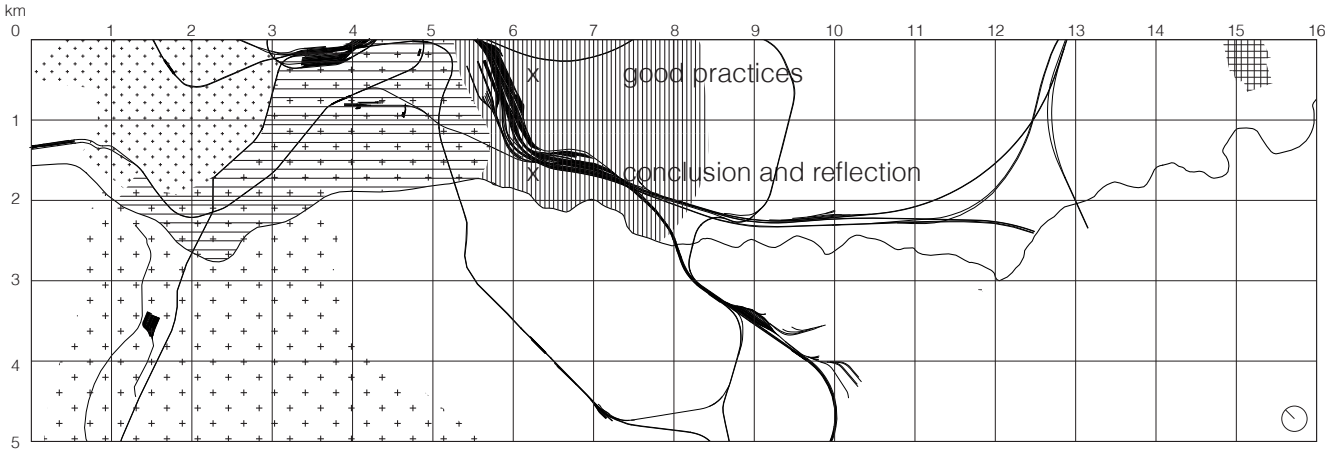
x cataloguing the operational territory

x good practices

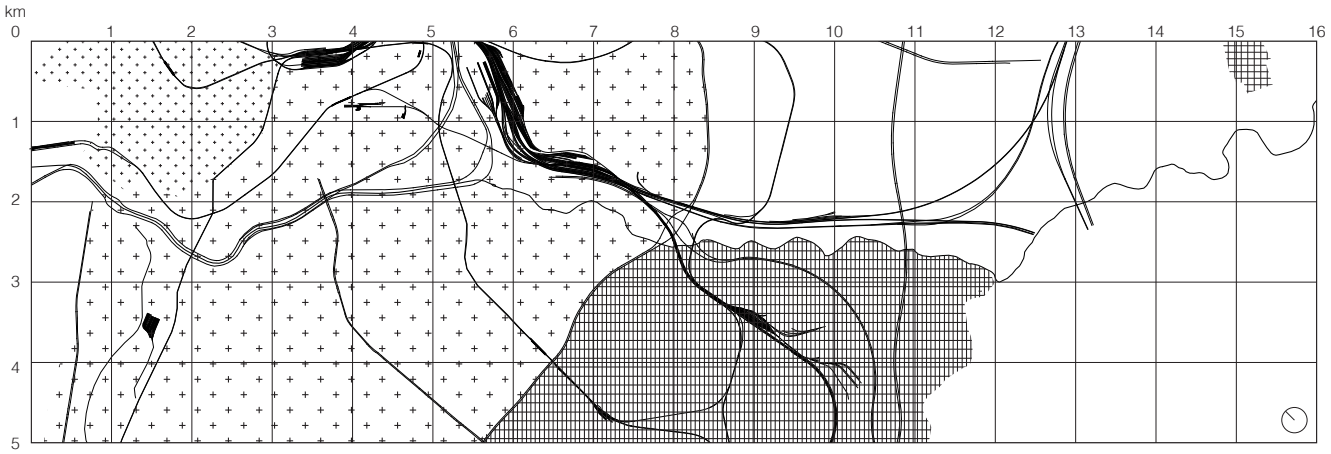
x conclusion and reflection



1850



1925



2025

urban

semi-urban

heavy operation

light operation

iv. contemporary symptoms of wasteful development

Following an understanding of the historic development of the 'operational territory', chapter four aims to understand the problematic symptoms emerging today in the neighbourhoods within this territory, stemming from the unequal and wasteful patterns of development which formed them.

Valdemingomez

Located in the southeast edge of the city, the Valdemingomez Technology Park is a major facility that handles household and commercial waste, receiving approximately 4,000 tons of waste every day (Ayuntamiento de Madrid, 2022). Although it is relatively detached from the centre of the city, it is in proximity to some residential areas, including a 16km-long informal settlement, which houses some of the poorest residents of the city, the Cañada Real. Here, almost 40,000 people live in a slum settlement, where many of the structures are built informally. Many of the houses here lack access to basic amenities such as power and water, leaving them especially vulnerable during winter months (Jones, 2021). Although the city boasts that the Valdemingomez facility incorporates several recycling processes and sustainable measures, the linear metabolic system which it serves is inherently flawed, and prone to problems. In 2021, significant quantities of methane were detected leaking from the waste treatment site through satellite images, and the polluting gas was seen drifting over nearby residential neighbourhoods (European Space Agency, 2021).

Villaverde

During my visit to Madrid, I was able to visit several neighbourhoods in the district of Villaverde, including San Cristobal, Villaverde Bajo and Villaverde Alto, including its large industrial estate. This visit was quite revealing to the degree of inequality which exists in Madrid, as I observed first hand the many social problems present in the area, including poverty, drug use and homelessness. Along the edges of motorways, or by the side of the train tracks below the 'Gran Via de Villaverde' were several clusters of informal shanty towns, mainly occupied by immigrant populations. Discarded trash was also seen frequently, with almost every square metre of available unused land being occupied by trash.

Vallecas

While Vallecas had relative economic success during the height of its productive

capacities, its de-operationalisation has now left it without a productive outlet or means of generating wealth, as its factories have been replaced by housing blocks. The district is now one of the poorest in the city, contrasting strongly with its former position as a relatively successful industrial hub (Instituto Nacional de Estadística, 2022).

Arganzuela

Although Arganzuela lost a significant portion of is industrial fabric, and operational processes are no longer existent in the district, the story of this district is not entirely unsuccessful. Following its de-industrialization, the district received significant investment, and underwent regeneration, especially between 1979 and 1999. In 1985, the Atocha overpass was demolished, and the roundabout was redesigned, and in 1987, the Peñuelas and Imperial stations were closed. The area continued to undergo transformations into the 2000s, with the construction of the 'Madrid Rio Park', which buried a section of the M-30 highway and converted the area into a park. Some operational leftovers in the district have also been preserved and converted into cultural centres; the old Delicias station is now a railway museum and archive, and the Matadero, the old slaughterhouse of the city, was converted into a cultural centre in 2005 (Arquitectura Viva, 2013).

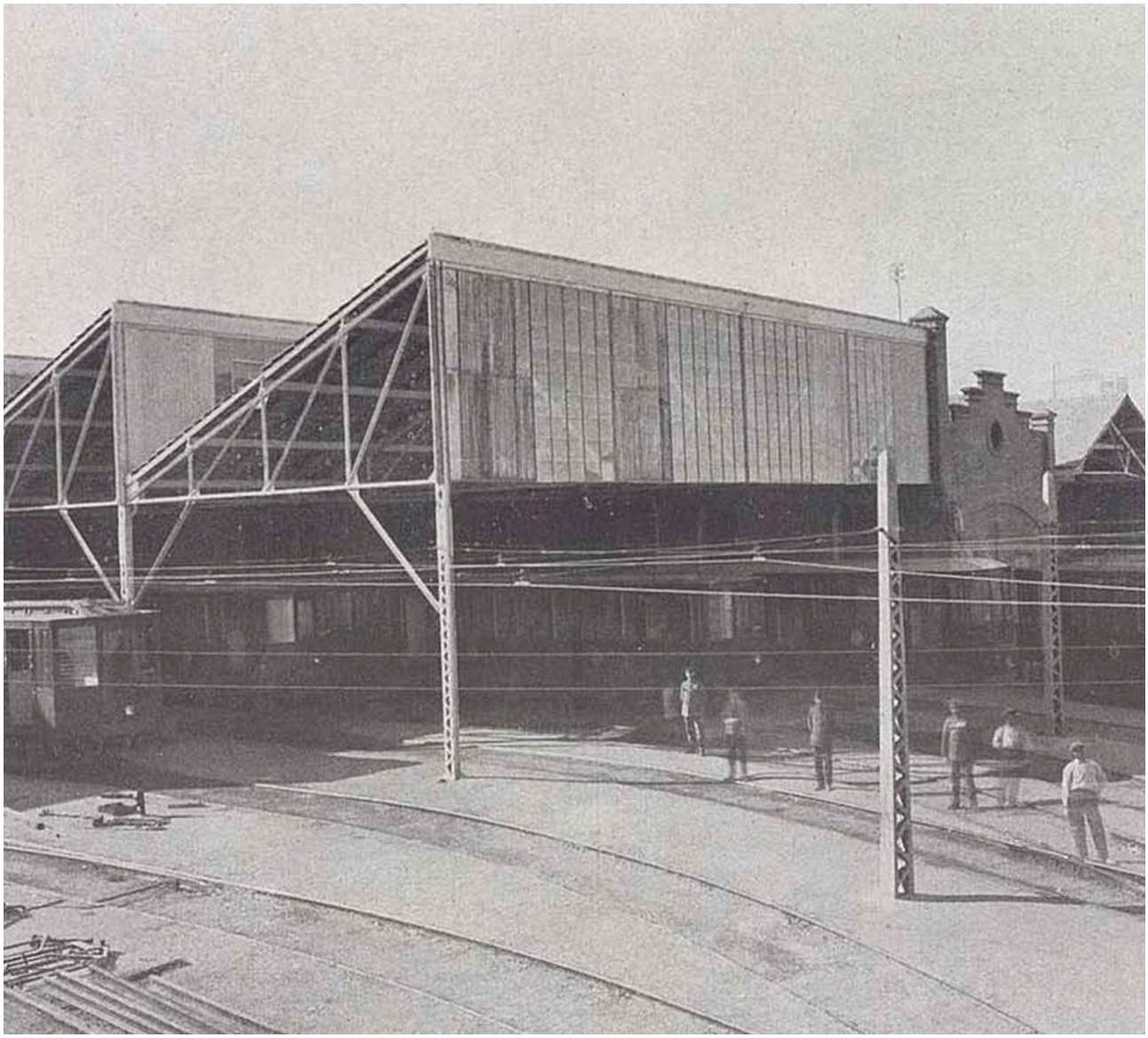
Upstream

Although Arganzuela offers positive examples of the ways in which operational leftovers can be utilised productively, wasteful developments continue to take place around the city, even in districts further upstream. In 2019, for instance, a cluster of historic railway maintenance sheds in Cuatro Caminos (figure 19) were demolished and are set to be replaced by a high rise and blocks including housing and office spaces (Navajas Josa, 2021). These structures dated back to 1917 and were designed by Spanish architect Antonio Palacios, an important figure, who had a hand in shaping Madrid's architectural identity in the first half of the 20th century. The sheds at Cuatro Caminos held significant historical and architectural significance, and in 2015, a 210 page document was published by 'Salvemos Cuatro Caminos', documenting their architectural qualities in an attempt to preserve them, but this was unsuccessful and their demolition proceeded (figure 20) (Valdés Menéndez, Sanz Muñoz, Fernández, & Bonet López, 2015). Several layers of wasteful development emerge from this case, as it involves industrial heritage being discarded, physical material being demolished

and likely landfilled, the removal of an operational process within the urban centre (and the potential for it to synergise with other processes), and the reliance on extractive streams to supply the new development.

figure 19 (page 39 - top)
cuatro caminos train depot in 1921 (Alamy).

figure 20 (page 39 - bottom)
demolition of the cuatro caminos train depot, 2021 (MCyP)




LOVE 4K

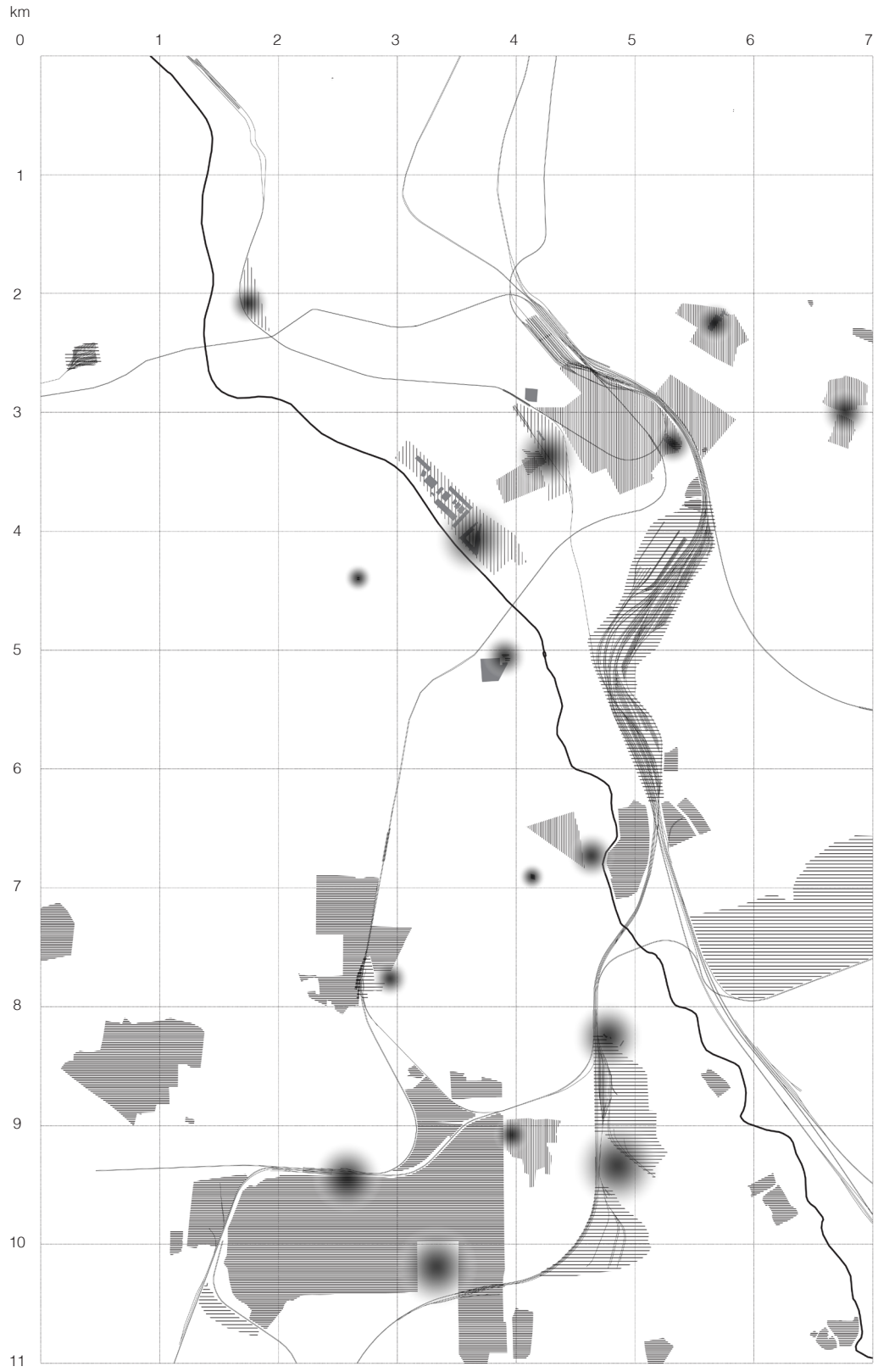
v. cataloguing the operational territory

The next step in the analysis of the operational territory (figure 21), following a historical analysis and an understanding of contemporary symptomatic issues, was the mapping of this territory using specific parameters which then led to the identification of sites where a new model of urban development could be instated, one which incorporates, rather than segregates diverse urban and operational processes. Using OpenStreetMap data from QGIS, alongside Google Earth satellite imagery, the areas mapped included: former/ongoing, light/heavy operational sites, operational leftovers, and their supporting infrastructures, namely the river and railway lines (figure 22). From this, sixteen sites were selected, with each site representing different spatial and temporal urban-operational relationships in the city today. These sites were then distilled into representations of varying degrees of urbanity or operational activity, former or ongoing, as well as the presence of network infrastructure, and exceptions such as leftovers and transit hubs (figure 23).

A matrix of characteristics was then applied to each site to help develop potential design strategies for them. This matrix involved ranking each site by the intensity of its urban or operational activity and the presence of relevant features such as transit stations or leftover structures. Through this analysis, potential programmes

figure 21 (left)
the operational territory (author, 2024)

figure 22 (page 41)
former/ ongoing/ light/ heavy operational activitiy, railway lines, the manzanares and potential sites of intervention within the operational territory (author 2024).



former heavy operation

ongoing heavy operation

river

former light operation

ongoing light operation

rail

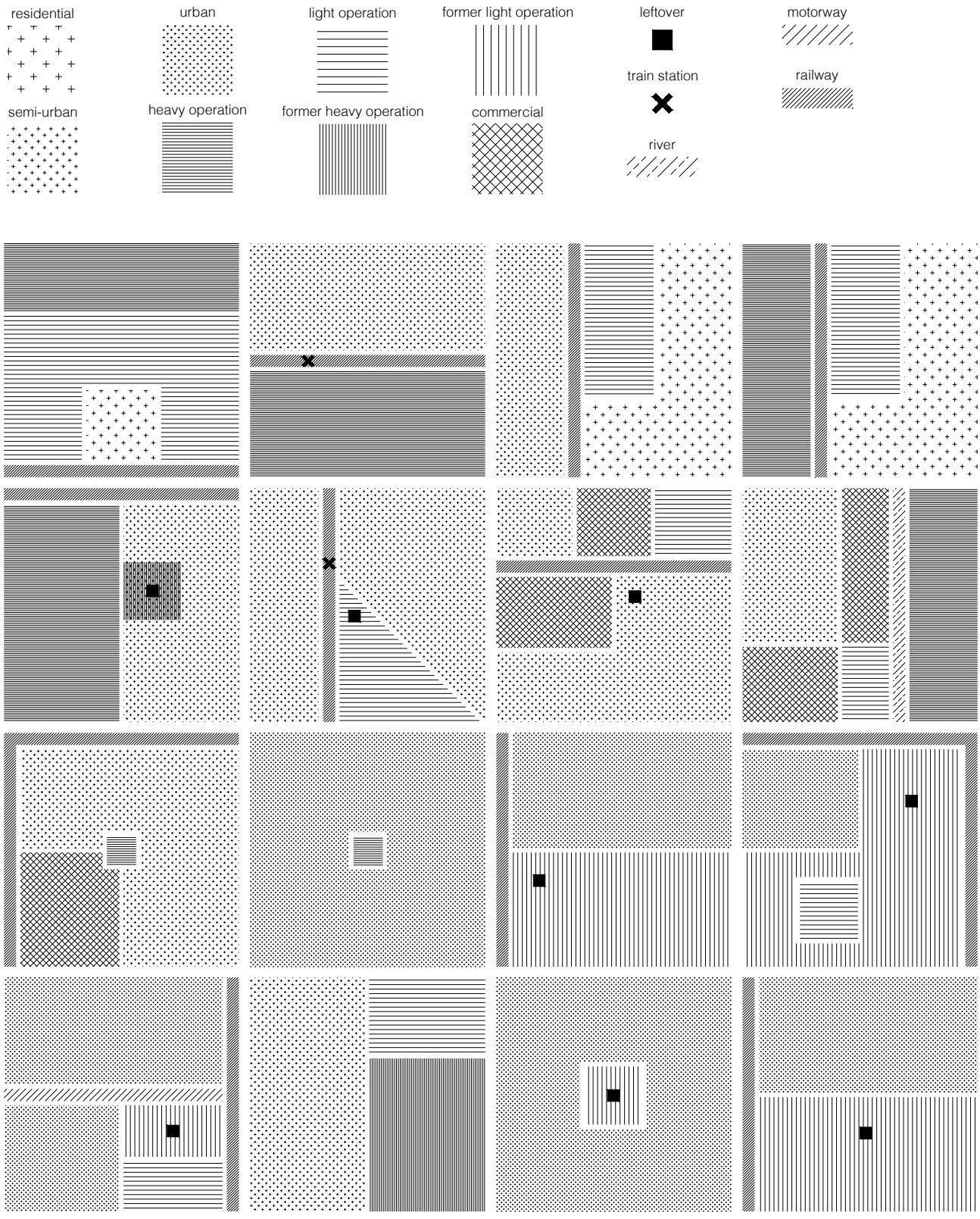
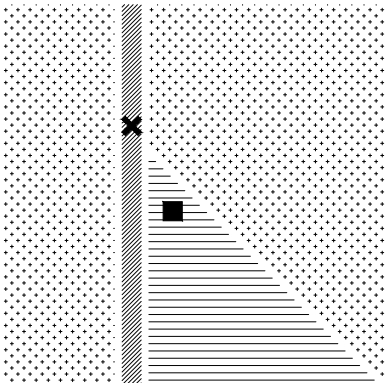


figure 23
spatial configuration of identified sites representing various urban-operational relationships in the city (author 2024).

and intervention strategies may be developed within each site where non-wasteful and economically, ecologically and socially productive interactions may take place between urban and operational processes in the city's periphery.

A site at **Villaverde Bajo**, which was initially identified through this mapping exercise was of particular interest to me and later became the site on which I further developed a design proposal (figure 24). The Villaverde district in general exhibits many of the wasteful and unequal metabolic systems prevalent in the city. The district is located directly downstream of the Manzanares, and is home to various operational activities, from the historic auxiliary railway industries to the newer industrial estate in Villaverde Alto. Its location at the edge of the city, amidst the most unfavourable geography of the territory, and home to numerous industries, has left the district to be systematically discarded by the city.

The site at Villaverde Bajo is historically rooted in the railway and its supporting industries, which date back to the late 19th century. In fact, residential areas cropped up after the railway and its industries landed on the site, as a supporting system for them. The site therefore represents a characteristic historic dynamic between the urban and the operational – here, the two worlds have a history of convergence and support. The complex at Villaverde Bajo historically was home to a railway yard, a train maintenance factory and workshops which performed several operations such as bridge repair, construction of steel structures and swing bridges, and the repair of shuttle cars and machinery. Simultaneously, a cluster of residential buildings housing the railway workers was constructed. These structures are of significant architectural value and are exemplary of early 20th century industrial architecture in Madrid. However, today many of these buildings are in a state of decay, as there has been a lack of care and restorative efforts taken towards them (Cronistas Villaverde, 2012).



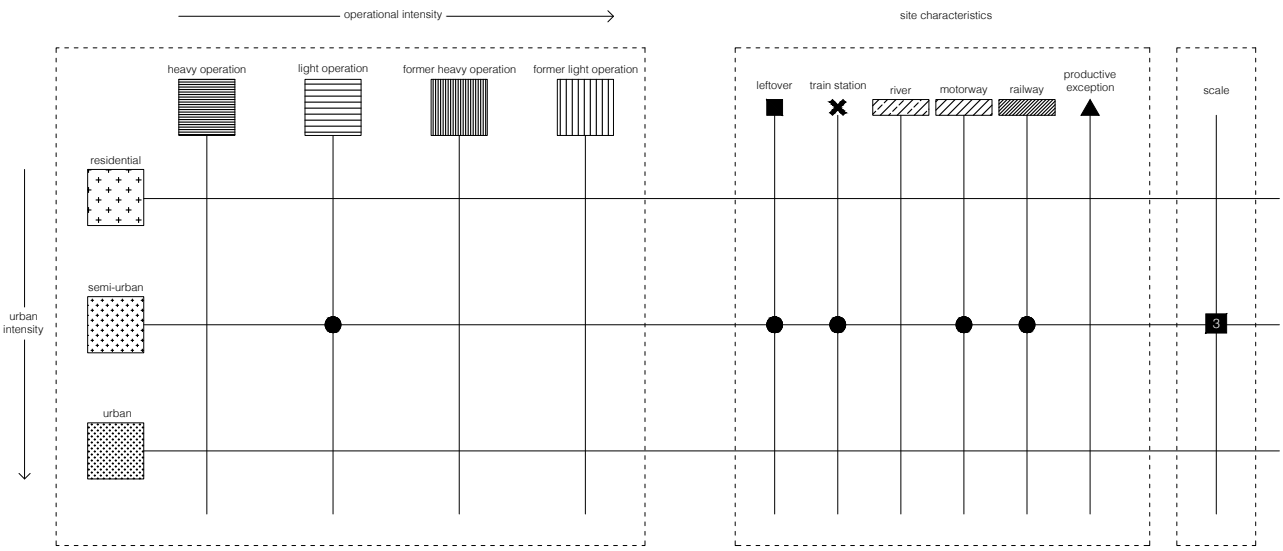

operational intensity
heavy operation
light operation
former heavy operation
former light operation
residential
semi-urban
urban
urban intensity
site characteristics
leftover
train station
river
motorway
railway
productive exception
scale
3

figure 24 (page 44)
applying the site
analysis methodology
to a potential site
of intervention at
villaverde bajo

vi. good practices

A compilation of good practices and practical references was useful in approaching an answer to the guiding question throughout the research, which has been a hypothetical one asking '*What if the existing metabolic processes of extraction, supply and disposal in Madrid's periphery could be rethought, and a socially, economically and ecologically productive process could be instated for peripheral communities?*'

Inspirational Entry Points

Kiel Moe's interview with the Berlage from 2022, titled 'On Ecology', was an entry point for much of the research, as it offered initial inspirational examples of contemporary architects building responsibly by not only mitigating the effects of unequal exchange and degradation associated with the modern architectural practice, but offering something productive to the operational landscapes that supply the construction site in return. Moe, for instance, who uses timber in many of his projects due to the location of his practice, aims to design extraction processes that enhance the biodiversity of the forests he sources timber from rather than damaging it. Similarly, Gilles Perraudin, who makes extensive use of stone in his work, develops parks in towns adjacent to the quarries he uses, thus offering a socially and ecologically productive place for that community (Moe, The Berlage Sessions: "On Ecology" by Kiel Moe, 2022).

A striking example of ecologically productive extraction may also be seen in figure 25, where timber was extracted by cutting trees in different shapes, as part of an experiment to test which shape allows for optimal sunlight penetration into the forest floor, thus attempting to somewhat enhance the landscape through an extractive process (Manaugh, 2017). Pre-Columbian settlements in the Amazon also provide an inspiring example of how human habitation can integrate seamlessly with its surrounding metabolic processes, as these settlements left no visible traces of human impact and were only identified in the 1980s when a geographer observed geometric cuts into the earth through LIDAR scans from a flight over the Amazon (Tavares, 2016).

Targeted Strategies

To identify more grounded examples of specific strategies that may be taken, I then looked further into discussions on circular urban metabolism, projects or strategies which deal with post-industrial areas, and discussions on the social

figure 25
satelite image of an experiment which involved cutting trees in a forest on the Arkansas/Missour boder in various shapes to study which one had the most effective exposure to sunlight. This is a sensitive example of an extractive process that may actually stimulate forest recovery. (Manaugh, 2017)

potentials of bringing manufacturing back to urban centres.

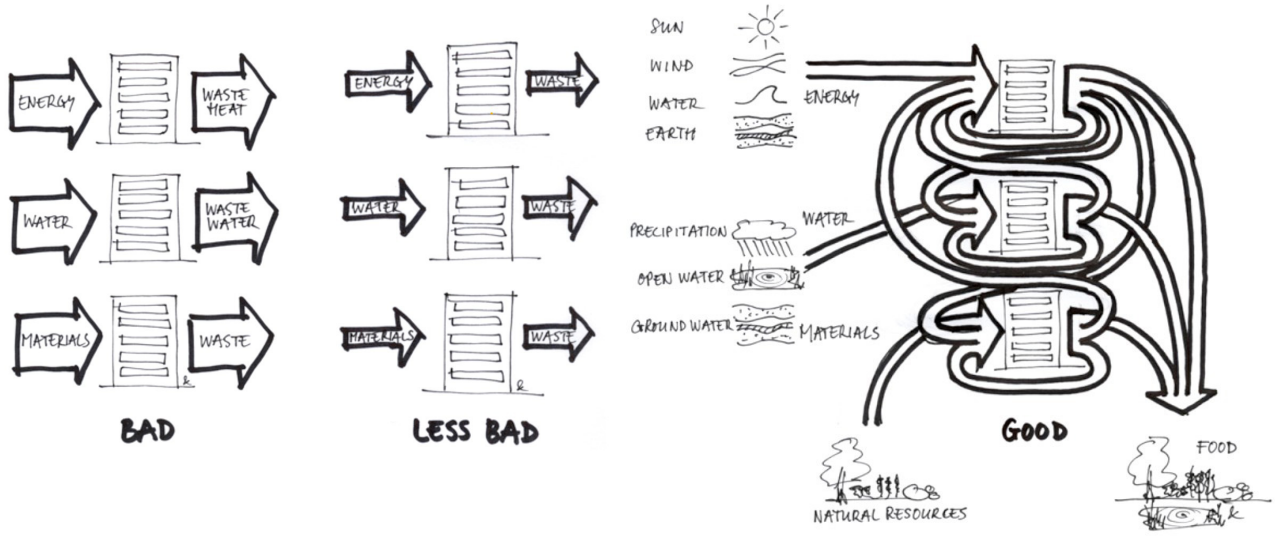
Urban metabolism offers a quantifiable framework which regards the city as an organic entity, one which consumes and expels physical matter and resources. Thus, the inflows and outflows of materials, energy and people can be understood, as well as the accumulation of resources (Derrible, Cheah, Arora, & Yeow, 2021). Several publications and projects investigate strategies which rethink the linear metabolic model existent in several cities globally, employing strategies which instate a circular system instead, where outflows can be reused and there is a reduced reliance on raw material extraction and dumping of waste into landfills. Viewing the city as an organic entity which consumes and expels matter was useful in understanding the city not as an isolated system, but as an organism continuously linked to the peripheral landscapes which supply it and perform the often problematic aspects of the metabolic process. The publication 'Urban Metabolism' by Fabrications, studies these inflows and outflows in the context of Rotterdam. Within the study, nine flows were highlighted: goods, people, waste, biota (the movement of plants and animals), energy, food, fresh water, sand or clay, and air, offering a quantifiable framework within which targeted design strategies could be developed (Tillie, Klijn, Frijters, Borsboom, & Looije, 2014).

When pushed to its limit, a circular metabolic model for the city means that there are absolutely no waste outflows, and all material resources extracted, as well as the resources naturally occurring in the city are converted into food. This is an approach conceived in the 2002 publication 'Cradle to Cradle: Reimagining the

Way We Make Things' (Braungart & McDonough, 2002), and further discussed by Andy Dobbelsteen in 'Towards Closed Cycles – New strategy steps inspired by the Cradle to Cradle approach' (2008). In this system, energy, water and material outflows are recycled, both into their own cycle (for example wastewater being used to supply the water demand) or applied to other cycles (such as wastewater being used to generate energy or new materials). Within this system, all 'waste' produced by the city becomes food, which is consumed again and used to supply the rest of the city's demand sustainably. The cradle-to-cradle approach has been applied to built projects such as in the Park 2020 in Hoofddorp, by William McDonough + Partners. Park 2020 is an office park development project of 114,000 square metres in the Netherlands which employed strategies of closing material cycles by modelling the urban development after natural ecosystems, aiming to reduce the use of resources and waste, while also extending the life cycles of the materials and objects used (Pineo, 2022).

A study on the development of Buiksloterham in Amsterdam similarly provided inspirational examples of strategies that may be taken to reconfigure material flows within an urban environment. While employing strategies akin to those in Park 2020, such as the exchange of flows between buildings (for example heat exchange), the project also emphasises a novel understanding of what it means for a city to be truly circular. "Circular Cities: Designing Post-Industrial Amsterdam – The Case of Buiksloterham" steps beyond the buzzwords often heard in relation to sustainable development. The authors emphasise the importance of providing the conditions for complex urbanity to develop semi-independently, through a bottom-up approach, where various actors who have a personal relationship to processes taking place in the area are directly involved and can collaborate with one another, and where communities are handed ownership, providing resilience

figure 26
Cradle to Cradle waste to food principle.



to the circular city (DELVA Landscape Architects, Studioninedots, Metabolic, 2016).

This study poses significant relevance in the development of potential intervention strategies for the sites mapped within Madrid's operational territory, due to their similarity. The study deals with a former monofunctional industrial area in relative proximity to Amsterdam's urban centre where new processes and programs are being introduced. The district is now transforming into a site of experimentation and innovation, as space is being given to self-builders, experiments are being carried out in the treatment of contaminated soil, new models of energy generation are being tested, and collectives are developing the district together. This approach is pluralistic, as an assemblage of new experiments and processes are taking place in a bottom-up, community driven manner, and collaboration between these different processes, combined with the use of the spatial and environmental conditions offered by the post-industrial site, create a resilient fabric for the new circular city, and a productive model of urban development.

> "We define the circular city as a resilient city that is capable of continuously reinventing itself. A healthy city that optimally makes use of flows of materials and maintains and strengthens the diversity of nature and culture."

Providing space for this complexity is essential in dealing with such sites and by offering the tools for sustainable development to cooperative alliances, initiators and developers, an alternative to the top-down, speculatively-driven models of urban development is generated.

In line with the theme of complexity and plurality – cultivating an urban environment where diverse processes coexist in close proximity and where varied actors are equipped to collaborate – the reintroduction of urban manufacturing emerges as a key strategy. Episode 19 of the City of the Future Podcast, titled "Next-Gen Manufacturing" explores how access to manufacturing jobs can be transformative for individuals historically excluded from the benefits of urban growth. These jobs often offer transformative wages requiring only a secondary education level, expanding access to economic opportunity (City of the Future, 2021). Introducing next-generation manufacturing into the city can yield multiple benefits: it creates access to employment through proximity and skills training, reduces reliance on extensive infrastructure by enabling walking or biking to work, and enhances urban resilience by decreasing dependence on global supply chains. In the episode, the hosts interview stakeholders involved in a project in Dorchester Bay,

Boston, a development that integrates affordable rental housing, affordable home ownership, office space, and industrial facilities. The project serves as a model for a next-gen manufacturing system that evolves with community needs and integrates diverse functions thoughtfully into the urban fabric.

By introducing these clean manufacturing industries - such as microbreweries, maker spaces, light industries and next-gen manufacturing, and food preparation services - communities historically marginalized by systems of unequal exchange and exposed to damaging industrial processes may instead gain access to more equitable and beneficial forms of operational activity. A compelling model that integrates operational processes with social systems is RotorDC, a cooperative company based in Brussels that is entirely employee owned. RotorDC reuses construction materials through dismantling, processing, and trading building components. By collaborating with contractors, real estate developers, non-profits, and other stakeholders, RotorDC has cultivated a regional ecosystem for material reuse that actively mitigates waste streams. Moreover, the cooperative ownership structure provides a socially equitable framework. This example demonstrates how waste flows can be reimagined and redirected into processes that integrate social and operational systems in mutually reinforcing ways (RotorDC, n.d.).

figure 27
RotorDC, Evere, Belgium (Pascal BROZE, 2022)

vii. conclusion

This research was guided by a speculative question: What if the existing metabolic processes of extraction, production and disposal in Madrid's periphery could be rethought, and a socially, economically and ecologically productive process could be instated for peripheral communities? At its core, this paper interrogates the systemic inequality and wastefulness embedded within contemporary urbanisation. As cities increasingly rely on peripheral operational territories - locally and globally - to sustain growth, these spaces are subjected to social, ecological, and economic degradation. This dynamic fosters a fundamentally unequal exchange between centres of accumulation and zones of operation. By drawing on theoretical contributions from various authors, including Kiel Moe, Jane Hutton, and Alan Berger, a framework was developed to critically examine systems of waste, inequality and operation in urban areas.

Madrid proved to be a fruitful context in which to situate this research, as the city's spatialisation has historically been focused towards the urban centre as the concentration of power within the city, with peripheral areas being blighted by inequality. Madrid's southern periphery in particular has been historically marked by extractive and manufacturing industries and disposal sites, often coinciding with areas of socio-economic disadvantage. This spatial and social inequality is not incidental but structurally embedded in the city's patterns of growth and urban governance.

One of the key findings was that Madrid's dominant mode of urban development continues to rely on *tabula rasa* practices, whereby existing urban fabric - along with its embedded social, ecological, and material value - are erased in favour of speculative, profit-driven projects. These projects treat their land as a blank slate, ignoring existing uses, processes, and histories. This approach perpetuates a segregation of functions: whereas early 20th-century Madrid integrated industrial and urban life in relatively central areas of the city, contemporary zoning practices have relegated operational processes to large-scale, monofunctional industrial zones, severing the potential for synergies between operational and urban functions to take place.

The research found that such segregation inhibits urban complexity and reinforces wasteful patterns. By contrast, urban plurality—understood as the integration of diverse functions, actors, and temporalities—creates opportunities for synergies, shared resources, and adaptive re-use. Complexity thus becomes a productive condition, reducing waste and enhancing resilience by enabling communication

between disparate urban processes.

These insights directly informed my development of a speculative architectural design proposal in a disused site in Villaverde, a southern district in Madrid. Rather than approaching the site through conventional redevelopment models, the design was grounded in an understanding of existing fabric, infrastructure, and urban processes. The proposal envisions a community-led cooperative, which integrates operational and social processes through mutual support. A material upcycling facility forms the core of the intervention, repurposing waste from surrounding industries and households into new resources. These materials are then redistributed through public marketplaces, embedding economic and social exchange within a circular system. Crucially, the design emphasises accessibility and integration – two concepts often neglected in conventional urban planning. By connecting diverse groups and processes, the project embodies a pluralistic urban model, serving as an alternative to the dominant pattern of segregation marked by wasteful urban development.

Although the research and design proposal are based in Madrid, the theoretical framework and methodology are broadly transferable to other urban contexts facing similar wasteful and unequal patterns of growth and operation. This research highlights the importance of readdressing urban metabolism not merely through technological solutions, but through systemic, socio-spatial reconfigurations. This research underscores that a meaningful response to systems of waste and inequality must begin with an acknowledgment and understanding of existing urban, operational and social processes. By incorporating plurality rather than discarding it, an alternative model of urban metabolism may be instated in the urban periphery which reinforces the diverse processes present. Doing so is critical, particularly at a time when we must collectively reassess our use of resources and improve the wellbeing of people living in disadvantaged conditions within our cities.

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