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Summary

This deliverable is based on activities conducted in READJUST's task 1.1. Based on a literature review and expert interviews, it summarizes inequalities in twin transition processes (linking green and digital transformations) in two sectors under study – the mobility sector and the agri-food sector.

1 Introduction

The term 'twin transition' refers to the simultaneous green and digital transition processes By uniting green and digital transitions to form 'twin transitions'. Both transition processes have the potential to accelerate each other (Muench et al., p. 7). These transition processes are facilitated by different political agendas. Therefore, twin transitions can simultaneously be understood from an analytical perspective, investigating if and how digital and green transition processes reinforce each other, or as well as a political concept with the aim to systematically use digitalisation for accelerating sustainable development (Wurm and Wittmann).

However, while twin transition processes have high potential to transform production and consumption towards more efficient and sustainable systems, the unintended consequences of such complex transition processes and their interaction need to be considered. The aim of this deliverable is to better understand the underlying mechanisms and manifestations of inequalities in twin transition processes in two sectors under study – the mobility and agri-food sector. The research question addressed within task 1.1 is formulated as follows: **What are existing or potential inequalities in twin transition processes in the mobility sector and the agri-food sector?** To address this question, we start from an open approach that maps inequalities related to both aspects of green and digital transitions. A literature review is conducted that combines keywords for green and digital aspects, linked to keywords referring to inequalities. Furthermore, expert interviews complement the literature review. Based on this qualitative approach, we find that the analysed literature refers to digitalisation as the main driver of inequalities while the green transition plays a complementary role. For each sector, the deliverable summarizes the technologies driving inequalities, the manifestations of inequalities in both sectors, vulnerable groups affected by inequalities, and distinguishes between inequalities created or amplified through twin transitions and inequalities positively addressed through twin transitions. Finally, we reflect on the inequalities described in the literature against the background of the EU Multidimensional Inequality Framework and further aspects of horizontal and spatial inequalities, which forms the basis of READJUST's inequality definition.

The deliverable is structured as follows. Part 1 introduces the aim of the deliverable. Part 2 summarizes the activities carried out in READJUTS's task T1.1 and describes the methodological approach. Part 3 summarizes findings on inequalities in twin transitions separately for the mobility sector and agri-food sector. Part 3 concludes by a joint reflection on inequalities in twin transitions in both sectors in relation to READJUST's multidimensional approach on inequalities. Finally, Part 4 draws conclusions based on these findings.

2 Description of Activities

The following Part 2 summarizes the methodological approach of this deliverable and the different steps of data collection and analysis.

2.1 Review of academic literature

To identify inequalities in twin transition processes and their manifestations in the mobility and agri-food sectors, a review of academic literature was conducted. The approach began with a search-string-based search using the Scopus database (www.scopus.com). This initial search focused on peer-reviewed articles, excluding conference papers and book chapters. Specific keywords were established for each element of the twin transitions (green and digital) as well as for social inequalities, along with sector-specific keywords for both the mobility and agri-food sector. These keywords were tested iteratively and redefined in several rounds to ensure a comprehensive coverage of all relevant journal articles. The final search terms used for the Scopus search are listed in Table 1.

Table 1: Keywords used for the literature search on Scopus

	Search terms
Inequalities	*equal* OR inequit* OR justice OR vulnerab* OR poverty OR employment
Digital aspects	technolog* OR digitiz* OR digital* OR smart OR cyber OR virtual
Green aspects	green OR environ* OR sustainab* OR climate OR ecolog*
Transition	transition OR transform*
Mobility sector	mobility OR transport
Agri-food sector	agriculture OR agri-food OR "food industry" OR "food sector" OR farming

This initial systematic search identified 111 articles for the mobility sector and 314 articles for the agri-food sector. After this, all abstracts of the identified articles were reviewed to exclude those articles that did not explicitly address twin transition processes in both the green and digital contexts or did not refer to aspects of social inequalities. During this first step, 11 relevant articles for the mobility sector and 9 articles for the agri-food sector were identified. Each article was analysed in-depth for the specific inequalities related to twin transitions, the various technological developments at play, and the underlying mechanisms driving inequalities. Following the Scopus search, additional articles, projects, and reports were identified through a snowball approach, for which the references within the selected articles were examined to find a broader range of studies related to inequalities in twin transitions (Table 2). This approach added additional 30 articles relevant to the mobility sector and 14 to the agri-food sector.

Table 2: Total number of reviewed studies

Sector	Initial Scopus search	Articles selected for review	Studies added through snowball approach	Total number of reviewed articles
Mobility	111	11	30	41
Agri-Food	314	9	14	23

Total number of reviewed articles in both sectors: 64

To analyse the articles and to identify inequalities described, we proceeded in two steps. In a first step, we created a spreadsheet that was structured along the following categories: 1) injustices caused by digital means, 2) injustices addressed through digital means, 3) technologies described, 4) geographical focus and 5) further relevant references. By reading the articles, the aspects described in the articles were noted for each category. In a second step, we clustered different types of inequalities identified in the literature and the underlying mechanisms described as drivers of inequalities. This clustering followed an inductive approach, informed by the findings in the literature. The results presented in part 3 of this deliverable are structured along the identified types of inequalities.

2.2 Expert interviews

To validate and interpret the findings of the literature review and to address any missing aspects, interviews were conducted with experts in the mobility and agri-food sectors, as well as those specializing in twin transition policies. Table 3 presents an overview of interviewed experts. Questions during the interviews concentrated on various types of inequalities, the factors driving these inequalities, and the role of different policies in creating or exacerbating inequalities (see Annex 1 for the interview guide). The interviews started with open-ended questions about the experts' perceptions of inequalities within twin transitions. After this initial discussion, the interviewees were presented a list of inequalities identified from the literature review. The interview partners were then asked to validate this list and suggest any further aspects they felt were relevant but missing from the literature findings. The results of these interviews are included in the discussion of the results in Part 3 of this deliverable.

Table 3: Overview of interviewed experts

No.	Interview Code	Stakeholder	Date	Duration
1	Int_1	EU-level policy expert (focus of the interview: on twin transitions)	21.08.2024	45 min
2	Int_5	EU-level policy expert (focus of the interview on mobility aspects)	19.09.2024	65 min

3	Int_2	EU-level policy expert (focus of the interview: sustainable development & justice)	25.09.2024	40 min
4	Int_6	Research expert on mobility transitions	08.10.2024	60 min
5	Int_7	EU-level policy expert (focus of the interview on green development)	09.10.2024	45 min
6	Int_8	Research expert on agrifood transitions	18.10.2024	60 min
7	Int_9	EU-level policy expert (focus of the interview on just transitions and agri-food aspects)	06.11.2024	60 min

2.3 Limitations

The key word search allows for a systematic approach to identify inequalities in twin transition processes. We complemented this with a snowball search of further relevant literature and validated the findings in expert interviews. However, the results are not to be understood as a full list of inequalities in twin transitions. For both sectors, inequalities might arise separately and reinforce each other, varying in their characteristics depending on the specific situational circumstances. Especially the combined approach to focus on both aspects of green and digital transitions lead to results that mostly focus on digitalization as a driver of transitions. Inequalities that are more closely related to green transition processes are therefore underrepresented in this study, as they do not necessarily refer to digital processes. Furthermore, the keywords chosen for the initial literature search do not distinguish between production and consumption aspects of mobility or agri-food sector transitions but tried to leave this open. Therefore, the results for the mobility sector rather focus on aspects of mobility consumption while the results for the agri-food sector focus on aspects of food production. Finally, what inequalities mean in a certain context or for certain social groups needs to be specified in depth for different cases and contexts.

3 Results & Discussion

For both sectors under study – mobility and agri-food – Part 3 summarizes the main findings on inequalities in twin transitions. The discussions on both sectors are introduced by a short overview of the existing sustainability challenges, a description of the relevant emerging digital technologies and a summary of existing as well as potential inequalities. Following this, the main themes of the underlying mechanisms that contribute to the emergence of the observed inequalities are discussed.

3.1 Inequalities in twin transitions: The mobility sector

The European mobility sector faces major environmental challenges as it emits almost 29% of all European greenhouse gases (GHG), a share that has been gradually increasing since 1990. While technological advancements have led to some efficiency gains, these have been largely offset by increased traffic volumes. The sector is also the largest contributor to nitrogen oxides in Europe, significantly impacting air quality and public health. Furthermore, mobility is a crucial source of noise pollution, which affects the health of millions of Europeans, as well as habitat fragmentation by dividing ecosystems into small, isolated patches. To achieve the European Green Deal's target of cutting emissions by 90%, the sector will have to undergo a comprehensive sustainability transition (European Environment Agency 2022)

Simultaneously, the sector is experiencing a rapid digital transformation (European Environment Agency 2022). Mobility as a Service (MaaS) platforms integrate public transport, ridesharing and bikes into a single digital application, making collective transport easier to access. Autonomous vehicles use sensors, cameras and artificial intelligence to navigate roads without human intervention. In logistics, automation uses robots and AI to perform tasks such as sorting and dispatching goods. Teleworking and online platforms allow for virtual mobility, reducing the need for physical travel. The use of big data analytics and Internet of Things (IoT) enables real-time tracking of vehicles and goods, which allows for smarter management of traffic and freight transport. Vast amounts of mobility data provide crucial information for transport policy, infrastructure investment or urban planning. However, the environmental benefits of digital technologies depend heavily on their management. For instance, lower costs and greater convenience can increase overall demand for transport, which may undermine sustainability efforts. Despite this, when managed effectively, digitalisation can support a transition to greener, more efficient mobility systems (European Environment Agency 2022).

The twin transition of digitalisation and sustainability has the potential to fundamentally change the way we move people and goods, while at the same time transforming the way we plan and manage mobility systems. However, such widespread changes are unlikely to affect all social groups equally. While some social groups may benefit from new opportunities, others risk facing deepened or new inequalities. Understanding these dynamics is critical for ensuring a just transition. The following section reviews the existing academic literature on how the twin transitions create, exacerbate or reduce patterns of inequalities and how they manifest in the mobility sector.

3.1.1 Overview of main findings

This literature review draws on a wide array of research disciplines—including urban studies, mobility studies, environmental science, digital technology and innovation, sociology, and public policy and governance—to provide a comprehensive understanding of the inequalities linked to twin transitions in the mobility sector. The integration of these diverse disciplines offers a more holistic understanding of how digitalisation processes, intending to meet the mobility sector's sustainability targets, intersect with complex questions of justice and equality. Several critical questions arise from the review: Who controls mobility data? Who benefits from the implementation of green digital technologies? Whose voices are heard in decision-making processes related to these transitions? What ethical concerns arise from data collection? How do twin transitions shape the future of work?

A key insight is that many inequalities stem from the introduction of sustainable digital mobility solutions by private companies, which are motivated by profit in a regulatory vacuum. However, the literature also highlights a range of opportunities to harness twin transitions to create more equitable mobility systems.

The literature review identified the following avenues for more equitable mobility systems (see Table 4 for an overview): First, digital technologies can enhance **access to sustainable mobility,** for example, through multi-modal journey planning, which helps to reduce reliance on private, fossil-based vehicles and fosters more efficient energy use. Initiatives such as virtual conferences and digital platforms reduce the need for carbon-intensive travel and the associated financial costs, thus enabling **digital connectivity** for people who would otherwise be excluded due to economic barriers or mobility restrictions. A range of digital solutions have the potential to cut air pollution in cities. As low-income and marginalized communities are more likely to live near large, polluted roads, twin transitions therefore contribute to **advancing environmental justice.** Furthermore, the use of digital tools can facilitate **equitable planning and decision-making-processes.** Digital data can help planners to identify safety gaps and underserved areas, while participatory tools might ensure underrepresented perspectives are included in mobility decisions. Finally, digital technologies can enable **enhanced digital advocacy**, for example by providing platforms for grassroots movements or enabling residents to document local mobility issues, thus helping communities influence transport policy.

Table 4: Inequalities addressed by twin transitions in the mobility sector

Theme	Inequality	Description	References
Mobility Accessibility	**Access to sustainable mobility**	Digital advancements can reduce the environmental impact of mobility while improving accessibility to greener transport options, e.g. through multi-modal trip planning, sharing services, or improved traffic flow management.	Anthony 2024; Creutzig et al. 2016; Creutzig et al. 2019; Lv and Shang 2023; Palm et al. 2021; Pappas 2021; Shaheen and Cohen 2020; Vargas-Maldonado et al. 2023
	Digital connectivity	Virtual conference and meeting platforms cut carbon emissions by minimizing travel and enable participation for those facing travel barriers, e.g. due to caring responsibilities, visa requirements, or financial costs.	Achten et al. 2013; Goebel et al. 2020
Environmental Justice	**Advancing environmental justice**	Digital advancements (e.g. electric vehicles) that reduce emissions, noise and air pollution benefit vulnerable groups, which are more likely to live near major roads and usually face greater exposure to environmental burdens.	Collins et al. 2020; Goebel et al. 2020; Hayward and Helbich 2024; Forkenbrock and Schweitzer 1999; Schlosberg 2007; Timmers and Achten 2016
Planning and Decision-making	**Equitable planning and decision-making**	Data collection and analysis through digital tools can enable more equitable planning, e.g. by identifying underserved areas or safety gaps. Participatory platforms like surveys and mapping apps can allow public involvement in decision-making.	Astarita et al. 2024; Behrendt and Sheller 2024; Creutzig et al. 2019; Gössling 2018; Henderson 2020; Karner et al. 2020; Kitchin 2014
	Enhanced mobility advocacy	Digital technologies can strengthen mobility advocacy by enabling data collection, awareness raising, and community engagement.	Agrawaal et al. 2024

However, the review of literature also provided curial insights into how twin transition risks create new inequalities or exacerbate existing ones (see Table 5 for an overview). The **digital divide** – the gap between those who can access and use digital technologies and those who cannot – creates a barrier to essential mobility services, as older adults, low-income or rural populations might not benefit equally from digital advancements. **Socio-economic barriers** further exacerbate this issue, as the costs of owning smartphones, maintaining internet access or subscription fees can limit access to new mobility solutions. Market-driven inequalities stem from the **dominance of private companies** in digital mobility solutions, as these firms typically prioritize profits over public good. Additionally, the **ownership of mobility data** by these private companies creates monopolistic control over crucial information, limiting competition, transparency and urban planning options. There are also significant **ethical and privacy concerns** surrounding the collection and use of mobility data, as individuals may face surveillance or unauthorized data access. Furthermore, reliance on quantitative data in mobility decision-making can lead to **epistemic injustice**, where nuances and lived experiences of vulnerable groups are overlooked. The **digital divide in mobility advocacy** prevents smaller organisations from accessing necessary digital data, tools and skills, potentially limiting their ability for mobility advocacy. The mobility twin transition may also lead to **job displacement** in the transport sector (e.g. in cargo handling and logistics) and a widening **skills gap**, as workers without technical expertise are left behind or are replaced. This situation is further exacerbated by the rise of the gig economy, which creates **precarious working conditions** for many, as they face a lack of employment protection, heightened surveillance and a lower sense of community, preventing collective action.

Table 5: Inequalities arising from twin transitions in the mobility sector

Theme	Inequality	Description	References
Mobility Accessibility	**Digital divide**	There is a gap between those who can access and use new mobility options, and those who cannot due to a lack of digital literacy, access to technological devices and internet services, or geographical location.	Durand et al. 2022; Durand et al. 2023; Goodman-Deane et al. 2021; Velaga et al. 2012
	Socio-economic barriers	Low-income communities might struggle to access green digital mobility options as essential tools: smartphones, internet, or EV charging stations are often unaffordable.	Goodman-Deane et al. 2021; Ermagun and Tian 2024; Khajehpour and Miremadi 2024; Palm et al. 2021
Market-Driven Inequalities	**Dominance of private companies**	New digital advancements are frequently driven by profit-seeking private companies, who might concentrate their efforts on wealthy urban areas or deploy innovations too rapidly without acknowledging infrastructure or accessibility needs.	Bandauko and Nutifafa Arku 2023; Castellanos et al. 2024; Creutzig et al. 2019; Goralzik et al. 2022; Kitchin 2014; Tomor 2019; Vargas-Maldonado et al. 2023
	Ownership of mobility data	A large amount of mobility data in private hands raises concerns about monopolistic control and limited oversight. Urban planners often have little or no access to	Behrendt and Sheller 2024

		this data, hindering effective planning.	
Planning and Decision-Making Processes	**Epistemic injustice**	An overreliance on quantitative mobility data in decision-making might lead to a neglect of the lived experiences and mobility needs of marginalized groups.	Behrendt and Sheller 2024; Henderson 2020
	Digital divide in mobility advocacy	Digital technologies for mobility advocacy require significant resources, creating a 'digital divide' that smaller non-profit and community groups often cannot bridge, as they might lack the financial resources, technical skills and infrastructure to manage complex data systems.	Agrawaal et al. 2024; Gray et al. 2018
	Ethical and privacy concerns	The collection of sensitive mobility data raises concerns about unauthorized access or misuse by corporations or authoritarian governments.	Creutzig et al. 2019; World Maritime University 2019
Labour Market Effects	**Job displacement**	Automation is likely to replace jobs involving manual or repetitive tasks in areas like transport or logistics.	Agrawal et al. 2023; World Maritime University 2019
	Skills gap	The shift toward specialized technological and digital skills puts low- and medium-skilled, older, and part-time workers at risk, especially when retraining is unavailable.	Chinoracký and Čorejová 2019; Polydoropoulou et al. 2023; World Maritime University 2019
	Precarious working conditions	Gig economy workers might lose social safety nets, while professions like taxi drivers see weakened community ties. Digitalisation heightens surveillance risks and productivity pressure.	Chinoracký and Čorejová 2019; Koivusalo et al. 2024; Polydoropoulou et al. 2023

3.1.2 Discussion of findings

The following presents a detailed discussion of the key findings from the literature review according to five themes: **Mobility Accessibility, Environmental Justice, Planning and Decision-Making Processes, Marked-Driven Inequalities as well as Digital Advocacy**. Within each theme, the potentials to contribute to greater equality as well as the risks of creating new or exacerbating existing inequalities through the twin transition are discussed.

Mobility Accessibility

Digital technologies have the potential to significantly improve the **access to sustainable mobility**, by providing greener, more resource-efficient alternatives to traditional vehicle use (Creutzig et al. 2016), while also catering to the needs of different social groups (Anthony 2024; Creutzig et al. 2019). Digital platforms and mobile applications support shared mobility and MaaS services like (electric) carsharing, bike rentals, and carpooling, which help to promote more efficient resource use while reducing reliance on private vehicles by closing gaps in transit services (Palm et al. 2021). These technologies also allow travellers to plan multi-modal journeys, seamlessly integrating various public transport modes and making it easier to choose sustainable options (Shaheen and Cohen 2020). As outlined in a study by Vargas-Maldonado et al. (2023), initial demonstrations of autonomous vehicles suggest that they could enhance equity by providing on-demand transport in areas lacking public transit. Intelligent traffic monitoring systems utilize real-time data collection to improve traffic flow management, which can significantly reduce emissions and make travel more efficient (Lv and Shang 2023). Transportation organizations can harness digital data to monitor and improve their mobility services using, for example, real-time updated digital twins (Rezaei et al. 2022). Open data platforms allow transport providers to share vital information about schedules, routes, and possible disruptions, thereby improving public transit accessibility and reliability (Anthony 2024). Such real-time updates and planning tools are specifically crucial for individuals with disabilities – as, for example, concluded by the EU-funded TRIPS project (Pappas 2021).

Additionally, digital platforms for video calls and virtual conferences help promote sustainability by cutting down on travel, significantly lowering carbon emissions while enabling ***digital connectivity*** for participants. Traditional face-to-face meetings often involve carbon-intensive air travel, but shifting to virtual platforms for academic conferences, business meetings and other events helps mitigate their environmental and climate impact (Achten et al. 2013). In addition, Goebel et al. argue (2020) that virtual events remove financial barriers, such as travel and accommodation costs, and enable wider participation, especially for people from low-income backgrounds or without access to visas. They can also benefit individuals with limited mobility or caregiving responsibilities, fostering broader inclusion and promoting equal opportunities for knowledge exchange and global collaboration.

However, despite the increasing availability of green and digital mobility technologies, their usage can be limited significantly by individuals' ability or opportunity to engage with them (Durand et al. 2023). The ***digital divide*** in mobility refers to the gap between those who can access and effectively use these technologies and those who cannot. According to a study of Goodman-Deane et al. (2021), the most affected groups are older adults, people with disabilities, rural populations, people with low levels of income or education, and migrants. Engaging with digital mobility services typically requires a certain level of digital literacy, including familiarity with smartphones, apps, payment systems, and the internet. Those who lack such skills face considerable barriers. Therefore, it is essential that user interfaces are intuitive and accessible, especially for people with disabilities and limited technical skills (Durand et al. 2022). Moreover, spatial factors come into play. Rural areas often lack high-speed internet infrastructure, making it challenging for residents to access these services compared to better-connected urban centres (Velaga et al. 2012).

Socio-economic barriers can significantly hinder access to digital green mobility options as well (Khajehpour and Miremadi 2024; Palm et al. 2021). For many of these options, owning a smartphone and maintaining internet access are prerequisites, but these are often unaffordable for low-income individuals (Goodman-Deane et al. 2021). Additionally, the need for a bank account or digital payment method can exclude vulnerable groups, such as homeless individuals, undocumented persons, or low-income individuals, who are less likely to have access to financial services (Palm et al. 2021). Subscription fees and per-trip costs are often designed with a wealthier, urban populations in mind, limiting affordability for those with lower incomes. Moreover, research, including a study by Ermagun and Tian (2024), shows that less affluent or minority communities often face economic obstacles in affording infrastructure, like EV charging stations, limiting access to sustainable transport options and thus contributing to spatial mobility inequalities.

Box 1: Mobility: Summary Mobility Accessibility

Which technologies are described as drivers of twin transitions? Digital platforms and mobile applications for shared mobility, autonomous on-demand driving, real-time updated digital twins, virtual conferences, digital payment systems, high-speed internet, electronic vehicles
What changes in twin transition processes? Greener and more resource-efficient mobility, reduced reliance on private vehicles, real-time planning of travels, reduced accessibility and affordability

Who is affected by inequalities in twin transitions? People with disabilities, older adults, rural populations, people with low levels of income, people with low levels of education, migrants, homeless people, undocumented persons

Environmental Justice

Advancing environmental justice in mobility refers to the fair distribution of environmental benefits and burdens associated with transportation systems (Schlosberg 2007). A key concern in this context is pollution, especially air and noise pollution, which disproportionately affects the health of low-income and minority communities living near major roads (Forkenbrock and Schweitzer 1999; Collins et al. 2020; Hayward and Helbich 2024). Air pollutants, such as fine particulate matter and nitrogen oxides,contribute to serious health problems, including respiratory and cardiovascular diseases, while noise pollution can worsen these issues by increasing stress and disrupting sleep (European Environment Agency 2024). Digital technologies can play a vital role in reducing pollution through electrification and traffic reduction. Transitioning to EVs in both private and public transport has the potential to reduce urban pollution and fossil fuel emissions, although studies indicate that the heavier weight of EVs is likely to mitigate the extent of these reductions (Timmers and Achten 2016). Additionally, digital solutions can reduce traffic congestion by promoting shared mobility services—such as carsharing and ride hailing—and optimizing routes through advanced traffic management. Virtual meeting platforms further minimize travel needs, contributing to lower traffic volumes (Goebel et al. 2020).

Box 2: Mobility: Summary Environmental Justice

Which technologies are described as drivers of twin transitions? Electric vehicles, shared mobility services, tools for traffic flow management

What changes in twin transition processes? Air and noise pollution

Who is affected by inequalities in twin transitions? Low-income and minority communities living near major roads

Market-Driven Digitalisation

Many green and digital mobility solutions are driven by corporate businesses. However, the ***dominance of private companies*** can be a source of significant inequalities and power imbalances (Kitchin 2014; Bandauko and Nutifafa Arku 2023; Creutzig et al. 2019; Boateng et al. 2022). Private firms typically need profitable business models, which often leads them to prioritize profit over the public good. Negative externalities might arise because private companies often deploy technologies rapidly, with little regard for infrastructure or urban planning priorities. Goralzik et al. (2022) argue that newly developed on-demand sharing services do not take the needs of disabled travellers into consideration. In addition, companies typically focus their efforts on geographical areas where they can maximize profits, which often leads them to invest in wealthier urban neighbourhoods (Tomor 2019; Vargas-Maldonado et al. 2023). As a result, lower-income urban areas and rural regions are neglected because of a lack of demand. This concentration of transportation services in affluent areas exacerbates spatial inequalities, leaving underserved communities with limited access to transportation options (Castellanos et al. 2024). As traditional fossil-fuel transport options decrease due to the green transition, a reliance on poorly regulated private digital mobility solutions might thus widen the mobility access gap.

Through digital technologies vast amounts of mobility data can be generated, e.g. through shared mobility services or multi-modal journey planning, providing valuable insights into transportation patterns. However, the ***ownership of mobility data*** by a small number of private companies raises concerns about monopolistic control over transportation systems, potentially affecting competition and public oversight (Behrendt and Sheller 2024). When corporations hold significant amounts of data,such as location, travel patterns, and user behaviour, they can gain considerable influence over individuals and public infrastructure (Creutzig et al. 2019). This concentration often leads to restrictions or financial access barriers to mobility data, which, one interview partner (Interview 5) argued, is rarely shared with urban planners or researchers, thus limiting its potential to improve transport services and inform urban planning.

The collection of private mobility data raises significant ***ethical and privacy concerns*** (Kitchin 2014). As services increasingly collect highly sensitive information, such as location and travel patterns, questions of surveillance and data protection arise. For example, GPS tracking in ride-sharing apps exposes users to constant surveillance, which, if combined with weak data security measures, can lead to unauthorized access and misuse. The concentration of data control in a few companies can force users to accept invasive practices to gain access to basic services. Real-world examples — such as the Chinese social credit system — illustrate the potential for abuse by authoritarian governments, where citizens are monitored for behaviour such as crossing streets at red lights and punished accordingly (Creutzig et al. 2019).

Box 3: Mobility: Summary Market-Driven Digitalisation

Which technologies are described as drivers of twin transitions? Digital technologies for shared or on-demand services

What changes in twin transition processes? Concentration of transportation services in affluent areas, data ownership concentrated in larger companies, collection of sensitive mobility data by private companies

Who is affected by inequalities in twin transitions? People living in low-income urban and rural areas, people using shared digital mobility services

Planning and Decision-making Processes

Digital technologies offer promising tools to enhance ***equitable planning and decision-making processes*** that align with the needs of different social groups. The datafication of mobility — through tools such as GIS technologies, real-time data from MaaS apps and platforms, and traffic sensors — provides mobility planners with extensive information on patterns of movement (Creutzig et al. 2019; Kitchin 2014). This comprehensive data enables the identification of safety gaps, such as missing crosswalks or bike paths, and underserved areas as highlighted by an interviewed mobility expert (Interview 6). Additionally, digital simulations, including digital twins of cities, facilitate in-depth analysis of different mobility scenarios, helping planners to understand potential shortcomings and mitigate risks before implementing changes (Astarita et al. 2024).

Digital tools can offer an opportunity to enhance participatory planning processes. Tools like surveys, social media platforms, or interactive mapping applications have the potential to empower citizens to share their opinions and needs, ensuring that a diverse range of perspectives is considered in decision-making. For instance, Gössling (2018) noted how an app developed by the Berlin-based “Bike Citizens” enabled travellers to map their biking patterns and donate them for research and urban planning. Online forums can facilitate discussions among stakeholders, promoting a collaborative approach to mobility planning. However, studies indicate that participatory processes can often serve as pro-forma exercises, with the results not actually impacting final decision-making processes (Karner et al. 2020).

While quantitative data provides valuable insights, it may be difficult to capture the underlying reasons for specific mobility patterns. This point was raised by an interview partner (Interview 5), who stressed the importance of understanding the nuances that numbers alone cannot convey. A neglect of qualitative, lived experiences of vulnerable groups and an over-reliance on quantitative data is referred to as ***epistemic injustice*** in scientific literature (Henderson 2020; Behrendt and Sheller 2024). This concern is also critical when considering the potential biases inherent in algorithms and artificial intelligence systems.

Additionally, digital technologies can support ***enhanced mobility advocacy*** by equipping advocates with tools to collect data, to raise public awareness, and to foster community engagement. This enables mobility initiatives to push for policies that improve both the environmental impact and equity of the mobility sector (Agrawaal et al. 2024). Kirkham et al. (2017), for example, utilized GPS-based evidence and video documentation to report instances of road inaccessibility faced by wheelchair users. Through digital tools, advocates can gather real-time, on-the-ground data on mobility issues, strengthening the evidence-base for their advocacy efforts. Social media and citizen journalism extend this reach, allowing individuals to report sustainability or justice concerns to a broader audience, while ensuring that advocacy reflects diverse community needs (Agrawaal et al. 2024).

However, the use of digital technologies usually requires substantial resources that not all organizations can access equally. This inequality can be understood as a ***digital divide in mobility advocacy***. Smaller non-profits and community groups often struggle to implement and use digital technologies equally. Building and managing the data infrastructure necessary can be costly and complex, requiring investments in technology, training, and ongoing maintenance. Gray et al. (2018) refer to this as ‘data infrastructure literacy’ – the ability to understand and interact with broader systems that generate and use data. Even large, well-resourced organisations face challenges in sustaining these systems, with difficulties such as siloed data, time-consuming manual data entry, and data warehousing problems. Agrawaal et al. (2024) thus argue that digital technologies can, in fact, become a barrier to urban planners or mobility advocates who work towards more equitable and sustainability mobility.

Box 4: Mobility: Summary Planning and Decision-making Processes

Which technologies are described as drivers of twin transitions? Digital twins of cities, digital tools for participation (e.g. surveys, social media platforms, interactive maps), digital algorithms, GPS-based evidence and video documentation of road inaccessibility, data infrastructure

What changes in twin transition processes? Identification of safety gaps and mobility scenarios, empowerment of citizens through digital participation methods, lacking data infrastructure literacy, biased algorithms

Who is affected by inequalities in twin transitions? Wheelchair users, non-profit and community groups

Effects on the Labour Market

Green and digital technologies are revolutionising transport industries worldwide, and their impact on the workforce, particularly in sectors like passenger transport, cargo, or shipping, presents both opportunities and significant social challenges. One of the most pressing challenges is ***job displacement***, as automation increasingly replaces repetitive or manual tasks in areas such as cargo handling, driving, and logistics (Agrawal et al. 2023). However, the extent of job displacement is expected to vary greatly according to specific sectors of the transport industry and country contexts, while its pace is estimated to be rather "evolutionary than revolutionary" (World Maritime University 2019, p. xvi).

Furthermore, the widening ***skills gap*** in the transport sector poses a significant challenge, particularly as advanced technologies like AI and robotics become more prevalent. Low- and medium-skilled workers are specifically at risk of being left behind (World Maritime University, 2019). Vulnerable groups include older employees and part-time workers, who might face barriers to access retraining, as Polydoropoulou et al. (2023) suggest. At the same time, roles that require higher technical skills, like big data analysis, are expected to grow. For instance, Chinoracký and Čorejová (2019) argue that in the future highly specialized skills, such as repairing autonomous vehicles, might become more relevant.

Additionally, the growing digitalisation in the mobility sector can lead to ***precarious working conditions*** (Chinoracký and Čorejová 2019; Polydoropoulou et al. 2023). The emergence of the gig economy, for example through platforms such as Uber, has resulted in workers being classified as independent contractors, which means they might lose their social safety net such as health insurance or entitlements to holidays. Many gig workers operate in regulatory grey areas where traditional labour protection does not apply, leaving them to exploitation. Studies also report that digitalisation goes hand in hand with heightened surveillance of workers, putting them under pressure to meet certain productivity targets as reported by an interviewed European Commission representative (Interview 5). In a study on Uber drivers in Helsinki, London and St. Petersburg, Koivusalo et al. 2024 describe that drivers experience a shift away from seeing their work as a profession with dignity and purpose, which could foster feelings of social dissatisfaction.

Box 5: Mobility: Summary Effects on the Labour Market

Which technologies are described as drivers of twin transitions? Automation in cargo handling, driving and logistics, mobility platforms (e.g. Uber)

What changes in twin transition processes? Job displacement, lack of skills, barriers to access retraining, exploitation and surveillance of workers, lacking sense of community

Who is affected by inequalities in twin transitions? Low- and medium-skilled workers, older employees, part-time workers, gig-economy workers

3.2 Inequalities in twin transitions: The agri-food sector

The EU agri-food sector faces pressing sustainability challenges due to the environmental impacts from inefficient fertilizer use, increasing reliance on chemicals for plant and animal health, inadequate waste management, high water consumption, and energy demands (Castillo-Díaz et al. 2023). Currently, this sector is responsible for 10.3% of the EU's greenhouse gas emissions (European Union 2020), necessitating a radical overhaul of farm designs, production methods, business models, and even consumer habits (Ollivier et al. 2018; Duru et al. 2015; Brunori 2022). To support these goals, new requirements under the Common Agricultural Policy (CAP), set by the European Commission, aim to help farmers improve their environmental performance (European Commission 2023a). The EU's Farm to Fork strategy further emphasizes the need for a green transition, aiming to not only lower climate and environmental impacts but also strengthen the global competitiveness of sustainable farming practices (European Union 2020). This sector-wide transition is crucial for reducing the environmental footprint of EU food systems and increasing resilience against climate change impacts, biodiversity loss, and future food security threats (European Union 2020).

The Farm to Fork strategy and CAP underscore the essential role of digitalisation in transforming the agricultural sector (European Union 2020; European Commission 2023a). The Farm to Fork strategy promotes the use of digital platforms to connect consumers with vital food information, which may influence their dietary choices, while CAP encourages farmers, fishers, and aquaculture producers to adopt innovative and smart production methods more rapidly. Precision agriculture[3], a key application of digitalisation, enables farmers to make data-driven decisions that improve resource efficiency, reduce waste, prevent the spread of diseases, improve food safety, and minimize environmental impacts,

[3] Precision agriculture leverages digital technologies—such as sensors, GPS, data analytics, and automated machinery—to monitor, manage, and optimize agricultural practices in real-time.

all while enhancing productivity and sustainability (Gebbers and Adamchuk 2010). In crop production, digital tools such as drones for seed sowing, IoT-based irrigation systems, and AI-driven pest and disease detection enable more informed and efficient farming practices (Brunori 2022; Birner et al. 2021; Bronson 2019; Florey et al. 2020; Gebbers and Adamchuk 2010; Wolfert et al. 2017). These technologies significantly lower the use of water, fertilizers, and chemical pesticides, contributing to the green transition's goal of minimizing environmental impacts. In livestock production, precision farming technologies, such as wearable devices that monitor animal health or regulate barn environments, improve animal welfare and productivity while reducing energy consumption (Birner et al. 2021; Rotz et al. 2019b). This not only enhances livestock productivity but also contributes to lowering emissions — a key aspect of the green transition. Moreover, digital advisory apps help farmers make informed decisions on fertilizers, feed composition, and eco-friendly products (Birner et al. 2021; Rotz et al. 2019a; Brunori 2022). Farm management software integrates various farm operations, allowing better tracking of resource usage and sustainability indicators (Birner et al. 2021). These digital tools not only improve efficiency but also help farmers meet the stricter environmental targets (European Commission 2023a).

Both digitalisation and green transitions share the overarching transformation goal in the agrifood sector, while they differ significantly in their dynamics and nature, their integration holds considerable potential for reshaping industries (Brunori 2022). It is assumed, that digitalisation offers powerful tools that can enhance efficiency, decision-making, and natural resource use (Florey et al. 2020; Birner et al. 2021), thus enabling and accelerating the green transition in agriculture (Myshko et al. 2024). However, while digitalisation has immense potential to drive the green transition, not all digital pathways lead to sustainability (Brunori 2022). In some cases, digital technologies may fail to align with environmental goals or exacerbate existing inequalities in access to resources (Klerkx and Rose 2020). The following sub-sections review the existing academic literature on the implications of the twin transitions, how they create, exacerbate or reduce patterns of inequalities and how these manifest in the agri-food sector.

3.2.1 Overview of main findings

The literature reviewed primarily focuses on digitalisation in agricultural production, examining how digitalisation impacts inequalities in this context. The literature is diverse and multidisciplinary, drawing from fields such as agricultural science, sustainability studies, innovation studies, and rural sociology. The topic is discussed with a wide range of perspectives—some optimistic about the benefits of digitalisation (Bronson 2019; Florey et al. 2020; Gebbers and Adamchuk 2010; Myshko et al. 2024; Wolfert et al. 2017), while others emphasize the controversies and risks (Rotz et al. 2019a; Rotz et al. 2019b; Stringer et al. 2020; Vázquez-López et al. 2021; Klerkx and Rose 2020; Kerras et al. 2022; Hackfort 2021; Fraser 2019; Brunori 2022). Mostly, the studies were based on qualitative research that explored the social and ethical dimensions of digital agriculture, including how power dynamics and inequalities emerge. Despite differing methodologies, a common thread across the literature is the recognition that, while digital innovations can drive sustainability and economic growth, their uneven adoption can create challenges which must be addressed.

The main focus of the studies is on inequalities that might arise in agricultural production, rather than on the consumption side. This means, the reviewed literature pays less attention to other key stakeholders in the agri-food value chain, such as processors and consumers, and how the twin transition affects them. For instance, ensuring affordable, sustainable food for consumers is crucial for an inclusive transition, yet policies to make sustainable food accessible to lower-income households remain insufficient, with existing efforts often failing to reach those in need (Interview 9). Additionally, reviewed literature on twin transition inequalities pays less attention to how the green transition might impact farmers, especially where it encourages reduced meat production. For many livestock farmers, agriculture is not only a livelihood but also a cultural identity and family legacy, and transitioning without culturally sensitive, viable alternatives risks marginalizing these communities and undermining their economic and social stability (Interview 9).

While digitalisation offers the potential to empower farmers through increased efficiency and improved decision-making, several critical risks arise from the review: 1) Digital tools are not suitable for all farmer types, with many of the existing tools tending to favour larger-scale or conventional farming operations. 2) Several articles underscore the challenges related to unequal digital access, for example Hackfort (2021) and Bronson (2019) highlighting that these technologies can exacerbate the digital divide, leading to new power imbalances and deepening existing inequalities, especially in rural communities. 3) The literature also reflects concerns about data sovereignty and labour exploitation, with some studies warning that without careful policy interventions, digitalisation may entrench existing inequities (Fraser 2019; Klerkx and Rose 2020).

The twin transition presents both opportunities and risks for addressing inequalities in the agri-food sector. Key opportunities identified in the literature (see Table 6 for an overview): Digital platforms offer the potential to bridge skills gaps by **expanding access to training and skill development**. Digital tools can offer **economic and social benefits** for small-scale and rural farmers (Rotz et al. 2019b) by boosting productivity and improving their livelihoods. Additionally, precision farming technologies help optimize resource use and promote sustainable practices, **reducing agriculture's environmental footprint** and supporting healthier local ecosystems and communities (Gebbers and Adamchuk 2010). Digitalisation also enables **an equitable subsidy distribution** by directing subsidies based on ecosystem services rather than land size (Martens and Zscheischler 2022), which particularly supports smaller and family-owned farms in a competitive market landscape.

Table 6: Inequalities addressed by twin transitions in the agri-food sector

Themes	Inequality	Description	References
Labour Market	**Access to Training and Skill Development**	Digital platforms can provide vital training resources and skill development opportunities for farmers. By empowering them to adapt to new technologies and practices, this approach helps to bridge the skill gap, enabling farmers to enhance their productivity and long-term sustainability in the industry.	Florey et al. 2020
	Improved Working Conditions	The agricultural sector is characterized by a reliance on low-skilled, temporary labour, leading to high turnover and subpar working conditions. Automation technologies, such as robotic milking systems and automated harvesting equipment, can reduce the need for repetitive tasks, creating more stable and skilled job opportunities.	Florey et al. 2020; Martens and Zscheischler 2022; Rotz et al. 2019b
	Economic and Social benefits for Small Farms and Rural Communities	Farmers in rural or underserved regions often face significant economic and social challenges due to limited resources and labour-intensive practices. Digital technologies, such as precision agriculture and online resource platforms, can significantly enhance productivity. By improving access to essential resources, including market information and financial services, smaller farms and communities can benefit from increased incomes and improved livelihoods, narrowing existing disparities.	Rotz et al. 2019b
Environmental Justice	**Reduced Environmental Impact**	Precision farming technologies, which optimize input usage and promote sustainable practices, can significantly reduce the environmental footprint of agriculture. This not only enhances the health of local ecosystems but also improves the quality of life for nearby residents.	Rotz et al. 2019b; Wolfert et al. 2017; Gebbers and Adamchuk 2010
	Equitable Subsidy Distribution	By shifting subsidy models to focus on ecosystem services rather than merely land size, the agri-food sector can provide fair support to a wider range of farm	Martens and Zscheischler 2022

		types. This change particularly benefits smaller and family-owned farms, ensuring they receive the necessary resources to thrive in an increasingly competitive landscape.	

However, the literature review reveals that twin transitions may also create or deepen inequalities (see Table 7). **The digital divide** limits rural farmers' access to necessary digital tools and high-speed internet, restricting their competitiveness (Martens and Zscheischler 2022). Digitalisation can also exacerbate **market power imbalances** by giving large corporations control over data and digital platforms, which can disadvantages small-scale farms (Hackfort 2021; Bronson 2019). Furthermore, data exploitation leaves farmers without fair compensation for their data contributions, widening economic divides (Martens and Zscheischler 2022). Moreover, skills inequalities are emerging, as smaller farms often lack the resources to adapt to new digital demands (Hackfort 2021), while economic disparities grow as larger farms are better equipped to invest in technology (Vázquez-López et al. 2021). Increased dependency on technology may also reduce the farmers' autonomy, tying them to specific providers and limiting decision-making freedom (Hackfort 2021; Birner et al. 2021). Lastly, automation threatens job displacement and labour exploitation, particularly for marginalized and lower-skilled workers, deepening socioeconomic divides in rural areas (Stringer et al. 2020).

Table 7: Inequalities arising from twin transitions in the agri-food sector

Category	Inequality	Description	References
Market driven inequalities	**Market Power Imbalance**	Digitalisation can exacerbate market power imbalances, allowing large corporations to gain leverage through data analytics and digital tools. These entities may dominate market access, pricing, and distribution channels, making it difficult for small-scale farmers to compete. Consequently, the market landscape may increasingly favour large agribusinesses, limiting opportunities for smaller farms and contributing to economic inequalities in the agricultural sector.	Hackfort 2021; Bronson 2019; Brunori 2022; Birner et al. 2021; Fraser 2019
	Data Exploitation	As farmers adopt digital tools, they often provide valuable data to technology companies, including information about their farming practices, yields, and market conditions. However, many farmers do not receive fair	Martens and Zscheischler 2022; Rotz et al. 2019a; Hackfort 2021; Fraser 2019; Mooney 2018

		compensation for this data, which is used by corporations to enhance their own profits. This exploitation deepens the economic divide.	
	Dependency on Technology	Digitalisation can lead to increased dependency on proprietary technology systems and platforms, which may limit the farmers' autonomy. When farmers rely on specific technology providers for vital tools and data, they may find themselves vulnerable to changes in pricing, policy, or availability. This dependence can reduce their ability to make independent decisions about farming practices, increasing corporate influence.	Hackfort 2021; Fraser 2019; Birner et al. 2021
	Economic Inequalities	There is a stark economic disparity between large and small-scale farmers regarding the adoption of advanced agricultural technologies. Large farms, with ample financial resources, can afford innovative technologies and manage the risks of rapid obsolescence. In contrast, smaller farms face significant financial hurdles that prevent them from making similar investments.	Hackfort 2021; Martens and Zscheischler 2022; Brunori 2022; Vázquez-López et al. 2021
Digital Divide	**Digital Divide**	The digital divide refers to the disparity in access to digital technologies and the internet, which remains significant across geographic and socioeconomic lines. Farmers in urban areas often have better access to digital tools, high-speed internet, and technological support compared to their rural counterparts. This gap can limit the ability of rural farmers to compete and innovate, exacerbating existing inequalities in agricultural productivity and income.	Martens and Zscheischler 2022; Kerras et al. 2022; Rotz et al. 2019b; Hackfort 2021; Florey et al. 2020; Brunori 2022
Labour Market Effects	**Skills gaps**	As digitalisation transforms agricultural practices, it necessitates new technical skills, such as data analysis, coding, and digital marketing. Many farmers, particularly those from	Hackfort 2021; Klerkx and Rose 2020

		low-income backgrounds or underserved communities, may lack access to training programs that equip them with these skills. This results in a widening skill gap, where those who can adapt to digital tools thrive, while others fall further behind, risking their livelihoods.	
	Job Displacement	The introduction of automation and digital tools can displace jobs, especially for lower-skilled workers. As tasks become automated and demand for manual labour decreases, many workers may become unemployed or underemployed. This creates economic insecurity for rural communities dependent on agricultural jobs, widening socioeconomic inequalities and limiting upward mobility.	Rotz et al. 2019a; Revenko and Revenko 2022; Stringer et al. 2020
	Labour Exploitation	Technological advancements in agriculture, such as automated harvesting and drone monitoring, often shift labour demands, leading to the exploitation of marginalized and racialized workers who are pushed into lower-paying, less secure jobs??.	Stringer et al. 2020

3.2.2 Discussion of findings

This sub-section presents a detailed discussion of the key findings from the literature review according to four themes: **Environmental Justice, Market-driven Inequalities, Digital Divide, and Labour Market**. Within each theme, the twin transitions potential to contribute to greater equality, as well as the risks of creating new or exacerbating existing inequalities, are discussed.

Environmental Justice

Digitalisation can help farmers to reduce their negative **impact on the environment** (Brunori 2022; Birner et al. 2021; Bronson 2019; Florey et al. 2020; Gebbers and Adamchuk 2010; Wolfert et al. 2017). Through smart farming, big data is leveraged to optimize farming practices, and by integrating real-time data with context awareness, smart farming allows for more dynamic and environmentally responsible management decisions (Wolfert et al. 2017). Additionally, digitalisation can help achieving more **equitable subsidies distribution** by transforming agricultural subsidy systems and facilitating targeted subsidies that support ecosystem services, rather than relying solely on land area-based allocations (Martens and Zscheischler 2022). This shift fosters more equitable agricultural support systems, where farmers who actively engage in environmental conservation and sustainable practices receive appropriate financial backing (Martens and Zscheischler 2022). By aligning subsidies with ecosystem services, digitalisation promotes practices that contribute to long-term environmental health while supporting farmers in their conservation efforts.

Box 6: Agri-food: Summary Environmental Justice

Which technologies are described as drivers of twin transitions? Smart farming, big data

What changes in twin transition processes? Equitable subsidies

Who is affected by inequalities in twin transitions? Farmers who actively engage in environmental conservation

Market-Driven Inequalities

Smart farming solutions, such as targeted harvesting based on sensors and neural networks or the use of wireless neck collars in animal husbandry (Idoje et al. 2021), often developed and distributed by large agribusinesses, can become more prevalent with the twin transitions, encouraging the adoption of such technologies for environmental and economic benefits (Brunori 2022). However, the effects of these technologies may vary by region, shaped by distinct market structures and agricultural landscapes. For instance, in the United States, large corporations drive the development of these technologies, potentially concentrating financial returns and widening the economic divide between corporate actors and individual farmers (Hackfort 2024). This might result in **market power imbalances**, driven by market dynamics and the growing influence of agribusinesses in shaping digital tools. The data used to build these platforms typically comes from sensors embedded in expensive machinery, which is easier accessible to large-scale industrial farms (Bronson 2019; Hackfort 2021). As a result, the solutions cater to conventional farming practices. For example, farmers without access to specialized precision machinery find much of the information provided by these platforms irrelevant (Hackfort 2021). In other cases, smart farming solutions do not cater to the needs of organic or other unconventional farming practices (Bronson 2019; Brunori 2022). For instance, digital decision support tools are often designed for high-profit crops like wheat and soybeans, making them less suitable for smaller mixed-crop farms (Brunori 2022). Additionally, some outputs of digital platforms (e.g., maps displaying "unprofitable" field areas or identifying areas needing fertilizer) are not suitable for organic farming practices (Bronson 2019).

This situation highlights the disproportionate influence of agribusinesses in shaping the digital tools used in agriculture (Birner et al. 2021; Hackfort 2021). These corporations control not only the design and application of technologies but also dictate their implementation (Bronson 2019; Hackfort 2021; Fraser 2019). Many digital tools lack interoperability, meaning that farmers who adopt a particular system often find themselves locked into a specific technology provider’s system. For instance, many farm equipment systems, such as tractors, seeders, and fertilizer spreaders require data exchange that is only possible when all equipment comes from the same manufacturer, creating walled gardens and thereby limiting a farmer’s choices and fostering market concentration (Birner et al. 2021). This lack of flexibility prevents farmers from switching to more affordable or effective solutions, creating a “**dependency on technology"** where farmers' ability to choose or adapt technology is restricted (Hackfort 2021; Fraser 2019). Addressing these challenges requires establishing global standards, such as the ISOBUS standard, which would ensure that different brands of equipment and digital tools can seamlessly communicate and exchange data (Birner et al. 2021). Furthermore, creating open, universal digital platforms that allow interoperability across different hardware and software providers could democratize access to agricultural innovations, reduce market concentration, and promote equitable technology adoption in the farming sector (Birner et al. 2021).

Further compounding this inequality is the issue of **data exploitation**. The data generated by these digital systems is typically owned and stored by agribusinesses and technology companies (Bronson 2019; Birner et al. 2021; Fraser 2019; Mooney 2018). Despite being the producers of this data, farmers rarely benefit from it directly and often have limited control over their own data (Rotz et al. 2019a). Instead, corporations use farmers’ data to improve their services, while farmers remain excluded from the profits or insights generated from their own information (Bronson 2019; Martens and Zscheischler 2022; Birner et al. 2021; Fraser 2019). This imbalance in data control exacerbates power disparities and limits the farmers' ability to negotiate fair terms or access alternative services. To counteract this, corporate-neutral, responsible open-access digital platforms are needed to centralize data collection and address the needs of alternative farming practices (Bronson 2019; Hackfort 2021). However, such applications remain far less available compared to private sector-driven solutions (Bronson 2019). Also, even if agricultural data is made ‘open,’ farmers may not have the skills or resources to analyse and interpret it effectively.

Thus, while digitalisation holds immense potential to drive agricultural innovation, its current market-driven nature exacerbates inequalities and limits inclusive access to its benefits.

Box 7: Agri-food: Summary Market-Driven Inequalities

Which technologies are described as drivers of twin transitions? Smart farming, sensors embedded in machinery, digital decision support tools, digital platforms, interoperability of technologies (tractors, seeders, fertilizers), platforms collecting agricultural data

What changes in twin transition processes? Growing influence of agribusinesses, reduced affordability of technologies for smaller farmers, dependency on technology

Who is affected by inequalities in twin transitions? Small-scale farmers, farmers with organic farming practices

Digital divide

As sustainability regulations tighten, such as mandated reductions in fertilizer use and stricter soil conservation practices, new technologies like precision agriculture can help farmers meet these requirements (European Commission 2023b). These digital tools can help improve efficiency and comply with regulations but come with significant cost, resulting in increasing economic **inequalities among farmers** (Rotz et al. 2019a; Hackfort 2021). Larger farms, with greater access to capital, are better able to invest in technologies like sensors, drones, and automated systems (Hackfort 2021). In contrast, smaller farms struggle to afford these investments, putting them at a disadvantage in adapting to new sustainability standards (Brunori 2022). The financial risks of digitalisation further widen this divide (Florey et al. 2020). New technologies are expensive, and their value can quickly decrease as innovations emerge (Hackfort 2021). Larger farms are more resilient and can absorb these costs, but smaller farms face higher risks (Hackfort 2021). As a result, those who can not adopt digital tools, are left unable to compete or meet stricter regulations, which widens the gap between large and small-scale operations (Stringer et al. 2020).

In addition to financial barriers, disparities in access to infrastructure, service providers, technology, and digital literacy create significant inequalities in the ability to adopt and scale digital tools in agriculture. Large-scale farms, for example, typically have better access to education and infrastructure, enabling them to acquire the skills to utilize advanced digital tools effectively (Hackfort 2021). These farms may also have the capacity to conduct in-house data analysis to optimize operations. In contrast, farmers in remote or marginalized rural areas face substantial barriers. Limited access to education, capacity building and training opportunities, coupled with weak institutional support for digitalisation, makes it more difficult for these farmers to adapt and benefit from digital advancements (Florey et al. 2020; Revenko and Revenko 2022; Kerras et al. 2022).

Additionally, demographic factors such as income levels, age, and rurality further contribute to the digital divide (Vázquez-López et al. 2021). For instance, younger farmers can be more open to using digital tools, heightening the generational digital divide (Interview 6). Whereas many rural farms lack the infrastructure needed to support digitalisation, including high-speed internet and reliable telecommunications (Martens and Zscheischler 2022; Rotz et al. 2019b; Florey et al. 2020; Brunori 2022; Vázquez-López et al. 2021). The situation is further compounded by insufficient investment in infrastructure in remote and rural areas (Hackfort 2021), exacerbating the divide, and leaving small-scale and rural farmers at a distinct disadvantage in the twin transition.

Box 8: Agri-food: Summary Digital divide

Which technologies are described as drivers of twin transitions? Precision agriculture, digital tools, high-speed internet and reliable telecommunications
What changes in twin transition processes? Affordability of technologies, lack of digital skills and low accessibility of training, lack of institutional support
Who is affected by inequalities in twin transitions? Smaller famers without access to capital, farmers in remote or marginalized rural areas, older famers, low-income farmers

Effects on the Labour Market

Digitalisation provides farmers with access to **better information, training, and skills development**, ultimately enhancing productivity and work satisfaction (Florey et al. 2020). For small scale and rural farmers, digitalisation can **improve working conditions** by reducing administrative, repetitive, and labour-intensive tasks, lowering operational costs, and offering flexible working hours (Martens and Zscheischler 2022; Rotz et al. 2019b). As a result, these changes have the potential to enhance overall productivity and work satisfaction. For example, in dairy farming, automation shifts labour demand from unskilled, temporary positions to more stable, skilled positions, promoting job retention and stability (Rotz et al. 2019a). However, digitalisation also highlights **skills gaps,** with new roles requiring data analysis, coding, and technology management—skills that often lie within tech companies rather than in rural agricultural settings (Klerkx and Rose 2020). This imbalance creates a dependency on corporate expertise, challenging individual farmers, particularly in rural areas, to compete effectively (Hackfort 2021).

Despite these benefits, digitalisation risks deepening labour inequalities, particularly for marginalizedand racialized farmers(Rotz et al 2019a). Technological advancements, such as automation, can lead to **job displacement**, especially for skilled agricultural workers, who may be replaced by temporary migrant labour for repetitive, low-skill tasks. This trend can **increase labour exploitation,** with marginalized workers left in positions offering minimal training and few opportunities for advancement (Rotz et al. 2019b). Compounding this issue are the associated financial pressures of digital adoption, which may drive some farm owners to cut costs elsewhere, such as in worker housing (Rotz et al. 2019b). This may exacerbate the precarious living situations of these workers but also reinforces their marginalization. The impact of **job displacement** is further shaped by geographical and demographic contexts (Klerkx and Rose 2020). Regions with high youth unemployment (Stringer et al. 2020) or dense agricultural workforces (Revenko and Revenko 2022) are likely to feel the impacts of job displacement more acutely, posing risks to local economic stability. Additionally, while digitalisation may create high-skill jobs in agricultural science and engineering, these roles typically require advanced education and are less accessible to low-skilled or rural workers (Rotz et al. 2019b).

Box 9: Agri-food: Summary Effects on the Labour Market

Which technologies are described as drivers of twin transitions? Automation

What changes in twin transition processes? Higher productivity and work satisfaction, job displacement, precarious living situations, reduced accessibility of advanced education to low-skilled rural workers

Who is affected by inequalities in twin transitions? Small scale and rural famers, individual farmers, marginalized and racialized farmers

3.3 Overall reflections on inequalities in twin transitions

The literature review and additional interviews showed that similar processes might influence inequalities in twin transitions in both sectors under study. In the mobility sector, as well as in the agri-food sector, digitalisation is described as the main driver of inequalities. New digital tools, automated technologies and data intensive platforms are assumed to contribute to more resource efficient and sustainable processes. While the literature on sustainability transition also highlights important aspects of inequalities that might arise from these processes, these inequalities are rarely described in combination with digital developments. Focussing on the twin transition processes, in which both aspects of green and digital are closely interlinked, we found that, in the majority of cases, the inequalities are related to effects that arise from digitalisation processes, while sustainability processes are only of subsequent importance.

Box 10: Summary of technologies driving twin transition processes

Technologies driving twin transitions in the mobility sector

- digital platforms and mobile applications for shared mobility
- autonomous on-demand driving
- real-time updated digital twins (of cities)
- electric vehicles
- automation in cargo handling, driving and logistics
- GPS-based evidence and video documentation of road inaccessibility
- virtual conference platforms
- digital payment systems
- high-speed internet
- datafication of mobility
- digital tools for participation (like surveys, social media platforms, interactive maps)
- digital algorithms
- data infrastructure

Technologies driving twin transitions in the agri-food sector

- precision agriculture (technologies for crop production, using sensors, remote sensing, simulation modelling, robots, drones, etc.)
- automation of farming practices
- digital decision support tools (advisory apps, farm management software, and digital platforms)
- high-speed internet and reliable telecommunications

One difference between the sectors under study is that, in the case of the mobility sector, inequalities are, for the most part, described in the analysed literature as taking effect on the consumer side, such as the affordability and accessibility of digitized and shared mobility services, while in the case of the agri-food sector, our analysis mostly found inequalities on the supply side, focussing on the divide between farmers and big corporations.

In the **mobility sector**, inequalities arise prominently among rural and low-income populations, who face barriers in accessing new modes of transport. Advancements in mobility technologies are typically concentrated in wealthier, urban areas, whereas rural or less affluent communities often miss the necessary infrastructure or resources to benefit equally (cf. EEA 2024). Furthermore, the twin transitions enhance inequalities caused by the already existing digital divide further. Vulnerable groups, including low-income, disabled or rural populations, migrants, and older adults, struggle to engage with digital mobility solutions due to limited access to technology and a lack of digital literacy (e.g. Durand et al. 2023; Goodman-Deane et al. 2021). That being said, the very same mechanisms leading or exacerbating these inequalities can also reduce existing inequalities in the mobility sector. Increased access to sustainable mobility options becomes available to larger segments of the population (e.g. Anthony 2024 or Vargas-Maldonado et al. 2023) and digital connectivity reduces the mobility needs in rural areas and allows a more equal access to economic opportunities at a lower environmental impact (cf. Achten et al. 2023 and Goebel et al. 2020). Similarly, digital tools can enable greater environmental justice, allowing more equitable planning, decision-making and advocacy in the mobility sector (e.g. Collins et al. 2020, Astaria et al. 2024 or Arawaal et al. 2024).

In the **agri-food sector**, the literature review revealed a strong focus on the inequalities on the production side of the sector, characterized for large parts by the significant resource and technological gaps between small-scale farmers and larger agribusinesses. While digitalisation offers tools like precision agriculture that can enhance productivity, these innovations are often inaccessible to smaller and marginalized farmers due to economic, geographic, and social barriers causing a digital divide which prevents them to adapt to the new modes of production, which are essential for meeting sustainability targets. These effects can lead to an increased concentration of markets, which in turn can cause a further entrenchment of existing disparities (e.g. Hackfort 2021; Martens and Zscheischler 2022; Rotz et al. 2019b). Additionally, the already existing market concentration leads to a disadvantage of smaller producers in other areas as well. Since smaller producers are unable to profit from scaling effects the same way as larger producers, skill deficiencies, economic inequalities, and data poverty increase, while an increased dependence on suppliers of technological solutions takes place (e.g. Klerkx and Rose 2020; Vázquez-López et al. 2021; Birner et al. 2021). However, similarly to the mobility sector, the academic discourse estimates twin transition to be able to become a positive factor increasing equality in the agri-food sector as well. This concerns specifically these cases where smaller farmers can profit from a combination of digitalisation on the one hand, and the increased demand for the products of more sustainable practices on the other. Here the biggest factors are the increased access to digital training and skill building, production increases in more challenging environments and farming practices, digitally enabled fair trade practices and subsidy distributions, as well as the possibilities created by the twin transitions to reduce the environmental impact of farming, resulting in higher revenues in specific market segments (e.g. Florey et al. 2020; Rotz et al. 2019a; Martens and Zscheischler 2022)

Box 11: Summary of manifestations of inequalities

What changes in twin transition processes in the mobility sector?

- greener and more resource-efficient mobility
- reduced reliance on private vehicles
- real time planning of travels
- identification of safety gaps and mobility scenarios
- empowerment of citizens through digital participation methods
- reduced accessibility and affordability
- air and noise pollution
- concentration of transportation services in affluent areas
- concentration of data ownership
- collection of sensitive mobility data by private companies
- biased algorithms
- job displacement
- lack of skills
- barriers to access retraining
- exploitation and surveillance of workers

What changes in twin transition processes in the agri-food sector?

- equitable subsidies
- higher productivity and work satisfaction
- growing influence of agribusinesses
- reduced affordability of technologies for smaller farmers
- affordability and dependency on technology
- reduced accessibility of advanced education to low-skilled rural workers
- lack of digital skills and low accessibility of training
- lack of institutional support
- job displacement
- precarious living situations

The literature review and additional interviews revealed patterns in which twin transitions exacerbate existing inequalities or introduce new potential disparities while reducing inequalities in other areas through new technologies, which level the playing field between socially, economically or spatially disparate groups and actors. This duality often plays out in parallel, where the same mechanism on the one hand increases equality for some groups, while simultaneously disadvantaging others. For both sectors we identified **market driven inequalities** due to the dominance of private companies as a major factor. Besides in extreme cases market failures, market concentration can lead to monopolistic control of data, data exploitation or dependencies in the use of certain technologies. Another major focus in both sectors is the **digital divide** as a cause for a disparate access to new tools. This divide manifests in the majority through the age or income of consumers in the case of the mobility sector, while the size and capital access for farmers are the main drivers in the agri-food sector. Additionally, in both sectors, inequalities are identified in relation to the effects that digitalisation might have on the **labour market**. Automation as well as highly complex digital technologies might lead to job displacement and contribute to a skills gap. New digital platforms e.g. in mobility services can also lead to precarious working conditions and labour exploitation.

Closely linked to these different themes that describe how inequalities manifest in the two sectors under study, our analysis identified different social groups affected by twin transition processes. For the mobility sectors, vulnerable groups are consumers of different types of mobility technologies and services. These groups might have reduced access to certain mobility solutions, or these solutions might not be affordable for them. In the agri-food sector, smaller farmers might have difficulties affording digital technologies that allow for more sustainable and efficient ways of production. For both sectors, inequalities refer to different groups of workers e.g. in logistics or farming.

Box 12: Summary of vulnerable groups affected by inequalities

Vulnerable groups affected by inequalities in the mobility sector

- people facing disabilities, wheelchair users
- older adults
- rural populations
- people with low levels of income
- people with low levels of education
- migrants
- homeless individuals
- undocumented persons
- minority communities living near major roads, people living in low-income urban and rural areas
- non-profit and community groups
- low- and medium-skilled workers

- older employees
- part-time workers
- gig workers

Vulnerable groups affected by inequalities in the agri-food sector

- farmers who actively engage in environmental conservation
- farmers with organic farming practices
- small-scale farmers (without access to capital)
- farmers in remote or marginalized rural areas
- older famers
- low-income farmers
- individual farmers

The analysis of inequalities did not start from a predefined understanding of inequalities but followed an open approach to identify themes of inequalities described in the literature. Finally, we reflect on how the identified inequalities fit into the EU Multidimensional Inequality Framework according through which the READJUST project defines inequalities. This framework describes inequalities across ten life domains: (1) knowledge and skills, (2) health, (3) material living conditions, (4) natural and environmental conditions, (5) working life, (6) cultural life and recreation, (7) political participation and voice, (8) social and family life, (9) bodily integrity and safety and (10) overall life experience. Additionally, horizontal inequalities, such as age or gender, and spatial inequalities between different local and regional areas complement READJUST's framework.

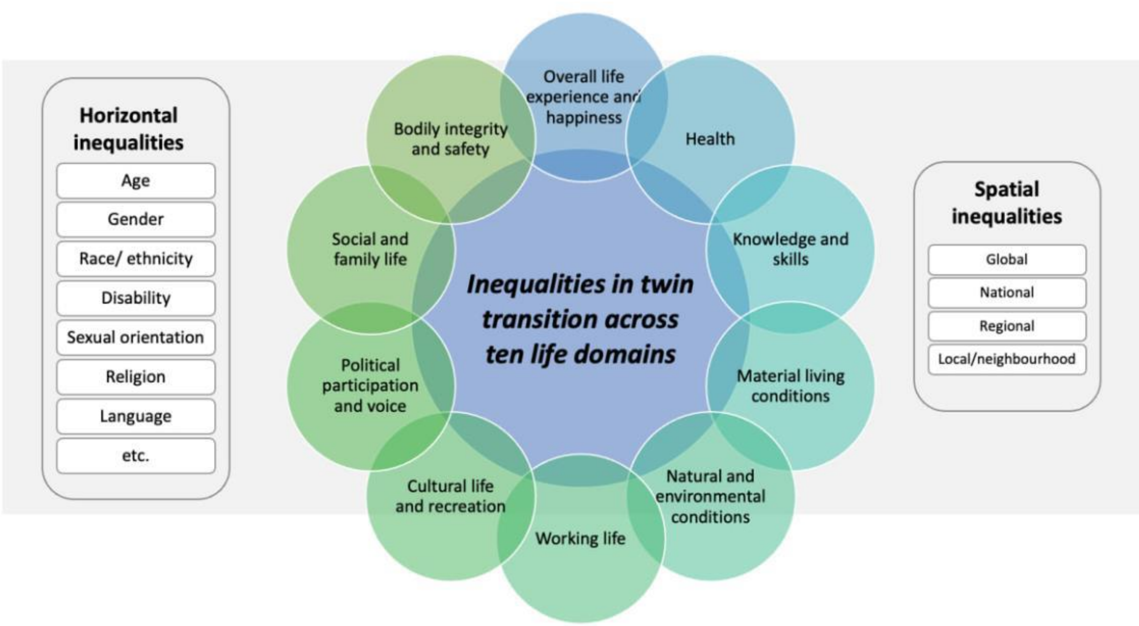

Figure 1 Adopted from EU Multidimensional Inequality Monitoring Framework

Source: https://composite-indicators.jrc.ec.europa.eu/multidimensional-inequality

The inequalities identified in this deliverable refer to the following domains and horizontal or spatial inequalities:

Table 8: Identified inequalities (addressed or created) across life domains

Knowledge and skills	e.g. digital divide, inequalities regarding access to training and skills
Natural and environmental conditions	e.g. advancing environmental justice through reduced emissions
Working life	e.g. job displacement, skills gap, precarious working conditions
Political participation and voice	e.g. equitable planning and decision-making due to digital forms of participation in mobility planning, enhanced mobility advocacy
Horizontal inequalities	e.g. inequalities related to mobility of people facing disabilities, wheelchair users; migrants, homeless individuals and undocumented persons as vulnerable groups in twin transition processes; older employees; marginalized and racialized workers
Spatial inequalities	e.g. reduced inequalities due to digital connectivity, concentration of transportation services in affluent areas

4 Conclusion

The aim of this deliverable was to identify inequalities in twin transitions in two sectors under study – the mobility and agri-food sector. The research question addressed is: **What are existing or potential inequalities in twin transition processes in the mobility sector and the agri-food sector?**

For each of the sector under study, we identified inequalities – either created, amplified or positively addressed through the twin transitions. The main themes of inequalities in the mobility sector are Mobility Accessibility, Environmental Justice, Planning and Decision-Making Processes, Market-driven Inequalities and Digital Advocacy. For the agri-food sector, the main themes of inequalities refer to Environmental Justice, Market-driven Inequalities, Digital Divide and Labour Market-related Inequalities. Structured along these themes, the deliverable also summarizes the technologies driving inequalities, the manifestations of inequalities in both sectors, as well as the respective vulnerable groups.

There are two possible perspectives on inequalities in the twin transitions. One perspective on the relation between the twin transition processes and the inequalities arising from these processes focusses mostly on digitalisation as a driving force. Herein, digitalisation enables increased sustainability by introducing more efficient means of production, distribution and communication (i.e. digitalisation being a driver for the sustainability transition), an interrelation which in turn might solve, cause new, or exaggerate existing inequalities. Another viewpoint puts the problems and necessities of the green transition (e.g. reduction of fossil fuel consumption, reduced use of fertilizers etc.) into focus. These necessities and problems, on which action is often mandated by legislation and regulation, need technical solutions (potentially) provided in turn by products of digitalisation. The resulting inequalities are therefore not so much driven by digital technologies changing the landscape, but by the (mandated) actions founded on the need for a sustainable transition. One main finding was that inequalities in twin transition processes are mainly described as related to aspects of digitalisation. The reviewed articles and insights from interviews mostly highlighted the **effect of digitalisation on inequalities** and only subsequently considered the environmental and sustainability aspects (positive or negative) of these trends.

To identify inequalities in twin transitions, we started from an open-ended approach based on a literature review complemented by expert interviews. This means that we did not start from a pre-defined definition of inequalities in the twin transitions, but rather mapped the aspects described in the literature that might lead to inequalities or address existing inequalities. Based on this approach, we reflected on main findings against the background of the EU's Multidimensional Inequality Framework, which is a structural part of the considerations on inequality in READJUST. We found that important domains of inequalities within this framework, which manifest in the two sectors under study affected by the twin transitions, are **knowledge and skills, natural and environmental conditions, working life, policy participation and voice**. Further **horizontal aspects,** such as age or disability, as well as **spatial inequalities** between rural and affluent urban areas could also be identified.

However, these results remain on an abstract level. More detailed and in-depth observations are needed to better understand how inequalities manifest in a particular local context, how inequalities are interlinked, reinforcing each other and affect different social groups.

5 Annex 1: READJUST interview guide

For READJUST's tasks T1.1, T1.2 and T1.3

PART 1: INTRODUCTION

- Could you briefly introduce yourself?
- From your perspectives, what are the most important aspects of twin transitions?
- If so, how is your work related to 'twin transitions'?

PART 2: TWIN TRANSITION POLICIES

- In your opinion, what are the 2-3 most important political measures for 'twin transitions'?
- In READJUST, we are especially interested in the food and mobility sector. Can you name important policies that address twin transition processes in these sectors?

PART 3: THEORY OF CHANGE / FACTORS DRIVING INEQUALITIES

- What have been the objectives of the important policies of green and digital transitions?
- "Green" covers a large variety of topics, e.g large parts of the 17 SDG domains. How do policymakers incorporate an optimal coverage of green-related topics in policies?
- How do policymakers ensure comprehensive coverage of digital-related topics in these policies?
- What do you think are the key indicators that should be measured to assess if the policy is working as intended?

PART 4: INEQUALITIES IN TWIN TRANSITIONS

- In your experience, do you have the impression that twin transition policies affect all parts of the societies in a (more or less) equal manner?
- Do you foresee social inequalities? Which ones?
- From your perspective, what types of social inequalities could arise / are visible in twin transition processes (in the food and mobility sector)?
- What factors drive inequalities in the context of the twin transitions?
- Regarding the policies we discussed before, do these policies address potential or existing inequalities?
- Assuming that the twin transition policies create or exacerbate inequalities in certain domains, are these inequalities perceived to be stable or temporary?
- In your opinion, what are the most important tasks for policy-makers with regard to inequalities in twin transitions?

PART 5: END

- Is there anything else you would like to share with us regarding inequalities in twin transitions?
- Who else do you think we should ask for an interview on this topic?

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