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Mass Collection of Workers' Data in Warehouse Facilities: Reflections on Privacy and Workforce Well-being

Thomas De Lombaert[*] – Arpan Rijal[•] – Robert Costrasal[+] – Michele Molè[α]

Abstract

Warehouses with complex monitoring and algorithmic management policies are rapidly expanding across the EU. This paper explores the functionalities of a Warehouse Management System (WMS) and its role in managing warehouse workers. In particular, WMS implementation raises concerns regarding worker privacy and data protection due to the increased surveillance of warehouse operations, while at the same time also having the potential to significantly enhance worker well-being. By examining the WMS' features in relation to the GDPR (EU Reg. 2016/679) and the AI Regulation (EU Reg. 2024/1689), this paper establishes a framework in which worker well-being is fostered in accordance with data protection and technology law. Following an introduction to these regulations, we analyse three case studies of personal data acquisition and management policies from warehouse management literature. Building on these examples, this paper offers practical guidelines for researchers and practitioners to ensure their warehouse operations comply with current regulations on worker monitoring. We show that data collection practices and their implications should be more carefully considered, both by practitioners and researchers.

Keywords: Warehouse Management System; Workplace surveillance; GDPR; AI Regulation; Worker well-being.

[*] PhD researcher at Research Group Logistics (LOG), Hasselt University (Belgium), where his research is funded by Research Foundation Flanders (FWO), Brussels, Belgium. Email: thomas.delombaert@uhasselt.be.
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[•] Assistant Professor, Department of Operations, Faculty of Economics and Business, University of Groningen. Email: a.rijal@rug.nl.

[+] LLM in Technology Law, University of Groningen. Email: costrasalrobert14@gmail.com.

[α] PhD researcher in Labour Law, Faculty of Law, University of Groningen. My PhD project is funded by the Cybersecurity Noord Nederland Project (CSNN). Email: michele.mole@pm.me.

1. Introduction: warehouses, workers' well-being, and data protection.

Labour studies, particularly in legal and sociological contexts, often examine warehouse facilities as a key example of organisational innovation driven by digital technologies for workforce management and monitoring. Amazon frequently emerges at the centre of this discussion, known (and criticised) for its stringent warehouse operations and their impact on workers' well-being.[1] Following years of debate on workers' rights and well-being in those warehouses,[2] in December 2023, Amazon's French subsidiary was fined €32 million for violations of core principles of the General Data Protection Regulation (GDPR, EU. Reg 2016/679).[3] The French Data Protection Authority (DPA) found that opaque data collection practices and the relentless work pace, dictated by monitoring systems, placed undue pressure on employees, leading to significant negative repercussions on their well-being.[4] The DPA, in reaching these conclusions, leveraged GDPR's principles such as data minimisation (Article 5(1)(c)) and assessed whether Amazon had a legitimate interest in establishing such intrusive data collection practices (Article 6(1)(f)).

However, well-being is a complex and multidimensional concept encompassing social, psychological, and physical aspects. The same monitoring and management tools that have negative impacts on workers' privacy can be leveraged to improve other aspects of worker well-being.[5] This is a topical research line in warehouse and operations management literature that argues for balancing different aspects of well-being while utilising novel monitoring and algorithmic management practices.[6] This begs the question of how data protection standards can be leveraged to improve worker well-being by influencing the design and management of warehouse environments.[7]

Sophisticated warehouses with intensive monitoring and algorithmic management tools are increasingly common in the logistics sector across Europe and worldwide, extending far

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[1] Delfanti A., *The warehouse: workers and robots at Amazon*, Pluto Press, London, 2021.

[2] UNI Global Union, *Life in the Amazon Panopticon: An International Survey of Amazon Workers*, 2023, available at: https://uniglobalunion.org/report/amazon-panopticon-survey/ (accessed 30 October 2024). Delfanti A., *Machinic dispossession and augmented despotism: Digital work in an Amazon warehouse*, in *New Media & Society*, 23, 1, 2021, 39–55.

[3] Molè M., *Minimised work surveillance exists under the GDPR: Amazon France and the DPA sanction*, in *Global Workplace Law & Policy*, 4th March 2024, available at: https://global-workplace-law-and-policy.kluwerlawonline.com/2024/03/04/minimised-work-surveillance-exists-under-the-gdpr-amazon-france-and-the-dpa-sanction/ (accessed 30 October 2024).

[4] Marassi S., Bolte J., *Leveraging Data Protection Law for Protecting Workers' Fundamental Right to Health and Safety in the Workplace: the Amazon Case*, in *International Labor Rights Case Law*, 10, 2, 2024, 263–268.

[5] Smith A.P., *An update on stress, fatigue and wellbeing: implications for naval personnel*, in *International Maritime Health*, 70, 2, 2019, 132–139; Corbett C.J., *OM Forum—The Operations of Well-Being: An Operational Take on Happiness, Equity, and Sustainability*, in *Manufacturing & Service Operations Management*, 26, 2, 2024, 409–430.

[6] De Lombaert T., Braekers K., De Koster R., Ramaekers K., *In pursuit of humanised order picking planning: methodological review, literature classification and input from practice*, in *International Journal of Production Research*, 61, 10, 2023, 3300–3330.

[7] Molè M., nt. (3); Marassi S., Bolte J., nt. (4); Molè M., *Surveiller et punir: Amazon Francia e la sanzione del Garante dei dati per la sorveglianza "intrusiva e pressante" dei suoi magazzinieri*, in *Diritto delle Relazioni Industriali*, 34, 2, 2024, 553–561.

beyond Amazon. Major multinationals such as Walmart[8] or Alibaba,[9] along with local enterprises like the Dutch supermarket chain Albert Heijn[10] or the Swedish retailer IKEA,[11] utilise various types of semi-automated warehouses. This paper takes an interdisciplinary approach, integrating perspectives from operations management and legal research, to examine whether EU data protection and AI legal standards can be leveraged by WMS designers (and managers) to promote innovative warehousing designs while safeguarding workers' rights and well-being.

By analysing data collection practices in warehouses, this research answers the following research question: How can the principles of the GDPR and AI Regulation be applied to establish legal standards for reducing intensive monitoring in warehouses and improving worker well-being? To answer this question, the paper proceeds as follows: Sections 2 and 3 discuss how a Warehouse Management System (WMS) works and which data are collected (and then processed) from warehouse workers. They do so through a depiction of the "order fulfilment process" in an illustrative warehouse and the employed tools (Section 2), alongside a discussion of the data collected (Section 3). This depiction helps to define in which ways a WMS could potentially mitigate pressing and intrusive monitoring of workers' activities. Then, moving from the Amazon France case, we look at the General Data Protection Regulation (EU Reg. 2016/679) (GDPR) and Artificial Intelligence Regulation (EU Reg. 2024/1689) as relevant standards and guidelines to promote workers' well-being while designing/operating a WMS. Section 4, in this regard, identifies relevant principles in Article 5(1)(c) GDPR ("Data Minimisation" principle) and in Article 6(1)(f) ("Legitimate interest" legal ground). We further highlight relevant obligations for employers in Articles 24, 25 and 35 GDPR. We then discuss new obligations arising from the AI Regulation, with particular reference to the Fundamental Rights Impact Assessment provided for by Article 27 AI Regulation. Throughout Section 4, we identify those standards that WMS developers and deployers (i.e. employers) should follow to prevent their WMS from establishing unnecessary and pressing monitoring of workers.

Section 5 applies these legal standards to three examples of personal data acquisition and management policies from the warehouse management literature. These studies focus on optimising warehouse efficiency which (in)directly impacts the well-being of warehouse workers. The approaches explored range from collecting data on workers' activities to using sensitive medical data (as defined by Article 9 of the GDPR) to prevent harmful work

[8] Repko M., *Walmart chases higher profits powered by warehouse robots and automated claws*, in *CNBC*, 11th April 2023, available at: https://www.cnbc.com/2023/04/11/walmart-warehouse-automation-powers-higher-profits.html (accessed 30 October 2024).

[9] Kharpal A., *Firm linked to Alibaba opens China's biggest robot warehouse to help deal with Singles Day demand*, in *CNBC*, 29th October 2018, available at: https://www.cnbc.com/2018/10/30/alibaba-cainiao-chinas-biggest-robot-warehouse-for-singles-day.html (accessed 30 October 2024).

[10] De Weerd P., *Dit is het nieuwe distributiecentrum van Albert Heijn*, in *Warehouse Totaal*, 19th April 2024, available at: https://www.warehousetotaal.nl/nieuws/dit-is-het-nieuwe-distributiecentrum-van-albert-heijn/132516/ (accessed 30 October 2024).

[11] IKEA, *How tech for show business can automate IKEA warehouses*, 19th November 2020, available at: https://www.ikea.com/global/en/stories/design/how-tech-for-show-business-can-automate-ikea-warehouses-201119/ (accessed 30 October 2024).

rhythms that compromise workers' well-being. The data collection and usage policies in these works are state-of-the art in the warehouse and operations management literature and have not been approached with a legal perspective. We analyse these studies in light of the GDPR and AI regulations to demonstrate that promoting workers' well-being and rights does not necessarily entail a blanket reduction in data collection. Instead, we explore how a WMS can be designed and operationalised in alignment with these regulatory principles to safeguard worker well-being, e.g. by collecting the appropriate amount and types of data, and by avoiding invasive monitoring practices. These findings are relevant not only for the development and adoption of new technologies in warehouses but also for academicians who propose new monitoring and algorithmic tools for management of the workforce. Section 6 offers concluding observations.

2. An illustrative warehouse.

All too often, Amazon receives the lion's share of media coverage on the deployment of comparable technologies for monitoring workers and collecting a plethora of data.[12] However, these technologies are extremely common and can be found in most reasonably sized warehouses. In fact, modern warehouses cannot operate without them efficiently. They can span across hundreds of thousands of square metres with hundreds of thousands of products some of which can look almost identical to human eyes.[13] The warehousing literature has acknowledged the value of these technologies in improving productivity and minimising errors.[14] The aim of this section is to provide a general overview of how warehouses operate and its implications for employee monitoring (through intensive data collection). Although warehouses vary widely in many aspects, we aim to describe the fundamental elements common to the sector. The described warehouse processes, operational methods, and employed technologies are therefore illustrative yet grounded in common practices within the industry.

Across warehouses, operational methods range from entirely automated to fully manual, according to the degree of human involvement.[15] Fully automated warehouses, i.e. those without human workers, remain a rarity to date.[16] These facilities are extremely capital-intensive and beyond the means of large companies. Since this paper's scope focuses on

[12] Palmer A., *Amazon is rolling out cameras that can detect if warehouse workers are following social distancing rules*, in *CBNC*, 16th June 2020, available at: https://www.cnbc.com/2020/06/16/amazon-using-cameras-to-enforce-social-distancing-rules-at-warehouses.html; Roethig O., Naranjo D., *Amazon's spying on EU workers just tip of iceberg*, in Eurobserver, 7th October 2020, available at: https://euobserver.com/opinion/149642 (both websites accessed 30 October 2024).
[13] Vijai P., Muralidhara G., *Inside Amazon: Chaotic Storage System*, in *IBS Center for Management Research*, 2016, available at https://www.thecasecentre.org/main/products/view?id=138531 .
[14] Winkelhaus S., Grosse E.H., *Logistics 4.0: a systematic review towards a new logistics system*, in *International Journal of Production Research*, 58, 1, 2020, 18-43.
[15] Dallari F., Marchet G., Melacini M., *Design of order picking system*, in *The International Journal of Advanced Manufacturing Technology*, 42, 1–2, 2009, 1–12.
[16] Azadeh K., De Koster R., Roy D., *Robotized and Automated Warehouse Systems: Review and Recent Developments*, in *Transportation Science*, 53, 4, 2019, 917–945.

workers' monitoring and their well-being, we limit our consideration to semi-automated and manual warehouses.

In general, three broad processes take place in a warehouse: receiving and putaway (inbound); order picking and sorting (processing); and shipping (outbound).[17] Specifically, a warehouse receives shipments from suppliers or manufacturers in large quantities, which are broken down into smaller packages and, if necessary, temporarily stored in designated areas before progressing to the next stage. Whenever a customer order arrives, order pickers retrieve the relevant items, after which these are sorted, packed, and shipped to the customer. The entire process from receiving an order to its shipment is referred to as the 'order fulfilment process' (see Figure 1). In the remainder of this section, we zoom in on this process and discuss the role of technology and the collected data in it.

2.1. The order fulfilment process.

Once a customer places an order, the order is transmitted and logged into the Warehouse Management System (WMS). The WMS is a collection of databases and algorithms maintaining information on the inventory of products and their locations in the warehouse. Furthermore, the WMS generates task schedules and regulates the operations of the entire warehouse.[18] In effect, the WMS is the brain of the facility and is often supported by technologies that provide real-time information from the warehouse floors.[19] This information may come in the form of both operations-related data (e.g., inventory levels, customer order status…) and human-related data (e.g., time-stamped picker transactional data, performance metrics…). The operational directives generated by the WMS directly impact the order picking process, which can be defined as the process of retrieving products from their storage locations in a warehouse. Within the order fulfilment process, order picking plays a critical role as it significantly influences the overall efficiency and accuracy, as evidenced by its contribution to 50% of total warehousing costs.[20] Occasionally, some remaining value-added activities occur, such as stickering, personalisation, or kitting, after which the products are shipped to the customer.

Given the aim of this paper, the focus is limited to the order picking function of the warehouse. This is due to it being the most capital- and labour-intensive[21] process in warehouses[22] and being the most technology-intensive warehouse area with a multitude of

[17] Tompkins J.A., White J.A., Bozer Y.A., Tanchoco J.M.A. (eds.), *Facilities planning*, John Wiley & Sons, Hoboken, 2010, 443.
[18] Richards G., *Warehouse management: a complete guide to improving efficiency and minimizing costs in the modern warehouse*, Kogan Page, London, 2014.
[19] Žunić E., Delalić S., Hodžić K., Beširević A., Hindija H., *Smart Warehouse Management System Concept with Implementation*, in *2018 14th Symposium on Neural Networks and Applications (NEUREL)*, 2018, 1–5.
[20] Tompkins J.A., White J.A., Bozer Y.A., Tanchoco J.M.A. (eds.), nt. (17).
[21] De Lombaert T., Braekers K., De Koster R., Ramaekers K., *What makes order picking so physically demanding? – Ergonomic evidence from a large-scale lab experiment using subjective metrics*, in *IFAC-PapersOnLine*, 58, 19, 2024, 181–186.
[22] de Koster R., Le-Duc T., Roodbergen K.J., *Design and control of warehouse order picking: A literature review*, in *European Journal of Operational Research*, 182, 2, 2007, 481–501.

technologies monitoring and managing employees. Any legal concern around data usage and monitoring in this area extends to other stages of the order fulfilment process.[23]

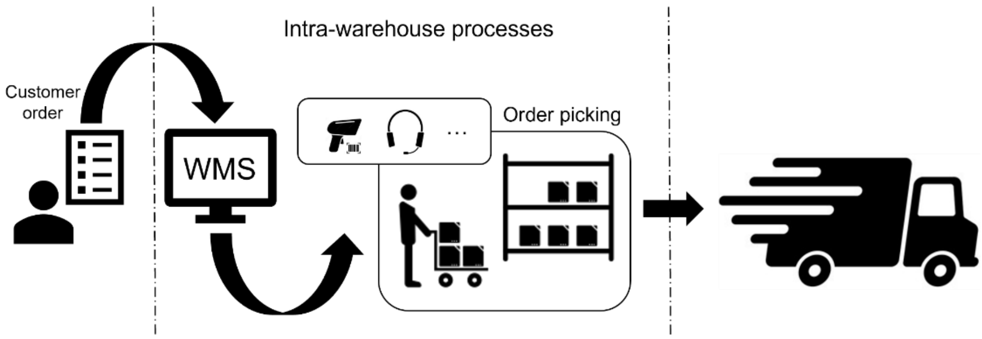

Figure 1. A generic overview of the order fulfilment process. (Source: created by the authors).

2.2. The role of WMS and technologies in order picking.

In a reliable order fulfilment process, the order picking process ensures the right product (quantity) is being collected. It can be argued that order pickers not supported by any technology in guidance and verification will have lower productivity and are more error-prone.[24] A modern WMS can assist in mitigating such operational inefficiencies even further, e.g. by generating intelligent task schedules.[25] The WMS manages the order picking process in the following manner. A suite of algorithms determines the most efficient manner to retrieve items in an order whilst respecting operational constraints (e.g. deadlines). The WMS transmits the tasks to order pickers wirelessly. Pick-by-voice and wireless scan guns are some common examples of these technologies. In the former, order pickers wear a headset with an earpiece and a microphone.[26] Over the earpiece, WMS transmits voice prompts about the location and the quantity of the following item pickers need to pick. When the order picker arrives at the location, s/he reads out a code identifying that location. If the location is incorrect, the order picker will be directed to the right location. Once the task is completed, the order picker speaks into a microphone acknowledging the completion of the pick and the WMS transmits the following pick order. With the use of scan guns, order pickers are provided pick order information about the following picking location through the scanner screens. The scanner can also then be used to scan respective barcodes to verify the right product location and the right quantity. Newer technologies such as virtual (or augmented)

[23] Delfanti A., Radovac L., Walker T., *The Amazon Panopticon*, UNI Global Union, Nyon, available at: https://uniglobalunion.org/wp-content/uploads/amazon_panopticon_en_final.pdf (accessed 30 October 2024).
[24] Guo A., Raghu S., Xie X., Ismail S., Luo X., Simoneau J., *A comparison of order picking assisted by head-up display (HUD), cart-mounted display (CMD), light, and paper pick list*, in *Proceedings of the 2014 ACM International Symposium on Wearable Computers*, 2014, 71–78; Richards G., nt. (18).
[25] Žunić E., Delalić S., Hodžić K., Beširević A., Hindija H., nt. (19).
[26] De Vries J., De Koster R., Stam D., *Exploring the role of picker personality in predicting picking performance with pick by voice, pick to light and RF-terminal picking*, in *International Journal of Production Research*, 54, 8, 2016, 2260–2274.

reality glasses are entering the market and could replace older technologies such as scan guns.[27]

Regardless of the sophistication of the technologies deployed, they serve three functions: (1) inform order pickers of the task to be done, (2) ensure the task is done correctly, and (3) communicate to the WMS about the progress of the order picking and shipment. The accurate and timely exchange of data between technologies and the WMS is crucial for the latter's efficacy. Up-to-date information on operational events ensures that the WMS is capable of effectively coordinating order-picking tasks. The data fed into the WMS can take many forms; for example, once a product has been picked, time-stamped data regarding this event enters the WMS via different technological devices. Hence, the WMS precisely knows the type of product picked by a specific worker, along with the exact time at which this action occurred.[28] These data and how they are used could serve many purposes in relation to the worker's well-being. This relation can either be negative (e.g., inciting the worker to work faster; creating stress by real-time error reporting, etc.)[29] or positive (e.g., preventing muscular injuries or reducing (mental) stress levels through job rotation etc.).[30] In some cases, these types of time-stamped data are complemented by picker-specific data, which may further impact this relation.[31] For instance, a priori knowledge regarding a picker's health status could tailor job rotations to individual needs and increase its efficacy.[32]

To this point, we have elucidated the role of (monitoring) technologies in the order picking process, as well as the critical role order picking plays within the broader order fulfilment process. In the following section, we move beyond these monitoring technologies and zoom in on the data they generate and feed into the WMS.

3. Data collection in warehouses.

Many different data types can be collected in the order picking process, either by technologies or manually, anonymously or not, as input for the WMS. We categorise the data collected and processed in warehouses into two main types: *systemic* and *personal*, with the latter having a higher degree of association with individual workers. While this distinction is practice-based in operational management studies, it aligns with the definition provided for by the GDPR. From an operations perspective, *systemic* data include impersonal data related

[27] Windhausen A., Heller J., Hilken T., Mahr D., Di Palma R., Quintens L., *Exploring the impact of augmented reality smart glasses on worker well-being in warehouse order picking*, in *Computers in Human Behavior*, 155, 2024.
[28] De Vries J., De Koster R., Stam D., nt. (26).
[29] Delfanti A., nt. (2).
[30] Calzavara M., Persona A., Sgarbossa F., Visentin V., *A model for rest allowance estimation to improve tasks assignment to operators*, in *International Journal of Production Research*, 57, 3, 2019, 948–962; Ongweso Jr. E., *Amazon's New Algorithm Will Set Workers' Schedules According to Muscle Use*, in *Vice*, 2021, https://www.vice.com/en/article/z3xeba/amazons-new-algorithm-will-set-workers-schedules-according-to-muscle-use (accessed 2 May 2024).
[31] An illustrative instance from our (the Authors) experience involves conversations with warehouse personnel, revealing a Muslim picker's aversion to handle products containing alcohol. Task assignments were manually rearranged to accommodate this preference. Integrating such religious considerations (data) into WMS could automate similar accommodations for the sake of worker comfort.
[32] De Lombaert T., Braekers K., De Koster R., Ramaekers K., nt. (6).

to specific warehouse processes or features, such as inventory levels or storage utilisation. Systemic data can also include worker-involved data, as long as it is impossible to trace it back to a specific worker. For example, aggregate warehouse productivity or picking errors can be considered systemic data, contingent upon ensuring worker non-identifiability, e.g., through anonymisation.[33]

Whenever data can be tied to a person-specific identifier, regardless of how far-reaching the inference may be, it becomes *personal* data. This level includes a wide range of person-specific data such as sociodemographics, anthropometrics, health-related data, etc. Differences among pickers in those contexts may be utilised to increase picker-task fit, resulting in ergonomic and performance improvements. For example, Steinebach et al. argue that accounting for picker height can improve ergonomics.[34] In many warehouses, the prevalent technologies enable the collection of highly detailed data, such as picking times, errors, and idle times, which are systemic if not relatable to a worker. However, in practice, these data are often linked to a unique worker identifier, thus qualifying as personal data under Article 4(1) of the GDPR. This allows the WMS to sketch the behaviour and performance of workers with high levels of accuracy. Hence, the company operating the warehouse acts as the data controller as defined by Article 4(7) GDPR and it is outlined as any "natural or legal person, public authority, agency or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data". Here, it is important to highlight that the legal interpretation of "personal" supersedes interpretations commonly applied in operational settings. From an operations point of view, data such as performance metrics or walking routes are not necessarily considered personal even when associated with an individual worker. Notwithstanding, any employer deciding to implement a WMS to run its warehouse and internal operations acts as a data controller since (s)he determines the purposes and means of the data processing brought by any WMS.

Personal data, ultimately, is any information that allows direct or indirect identification of the data subject.[35] As pointed out in the Recommendation 1/2001 on Employee Evaluation data by the Article 29 Data Protection Working Party (today, European Data Protection Board) both raw employees' data and derived evaluation data qualify as personal data under data protection law: "Personal data can be (...) found in subjective judgments and evaluations which can actually include elements specific to the physical, physiological, psychical, economic, cultural or social identity of data subjects".[36] Hence, any evaluation or instruction generated by the WMS constitutes personal data since it allows the identification of a particular warehouse worker. For example, establishing performance targets for workers and incentivising better performance are to be considered processing of personal data. Similarly,

[33] According to Article 4(1) GDPR, if any piece of information that does not allow directly or indirectly to identify a natural person, that is not personal data (hence, the GDPR won't apply).
[34] Steinebach T., Wenzel J., Wakula J., Elbert R., *The body height as an input parameter for a capability-based order assignment in manual order picking*, in *Frühjahrskongress*, 2021.
[35] Article 4(1) GDPR.
[36] Article 29 Data Protection Working Party, *Recommendation 1/2001 on Employee Evaluation Data*, 2001, available at:
https://ec.europa.eu/justice/article-29/documentation/opinion-recommendation/files/2001/wp42_en.pdf (accessed 30 October 2024).

detailed knowledge of the exact time a picker handled goods (e.g., recorded via his/her scanner) constitute personal data.

The plethora of information available to WMS and managers, as seen in the Amazon France case, may facilitate punitive actions by the company, e.g., disciplining order pickers in cases of inferior performance.[37] Intrusive data collection in warehouses, however, does not necessarily have negative implications; collection of granular data about workers' behaviour, even sensitive data, can have positive repercussions on workers' well-being (e.g., preventing muscular injuries or reducing mental stress through job rotation).[38] This shows the need for a careful balancing act between worker privacy and operational excellence.[39] Nevertheless, data collection acquires negative connotations, up to violations of privacy rights of workers and health and safety hazards, when the WMS design is solely centred around efficiency. In the Amazon France case (See Section 1), the DPA found that Amazon was reaching legitimate employers' interests such as employee evaluation, management, and training; yet, it was doing so by retaining an unnecessary wealth of data for the good operation of the warehouse. Those extensive datasets, not compliant with the GDPR's principles and obligations, allowed the management to issue strict disciplinary actions: employees in French warehouses could face retraining after just one day of underperformance.[40] In its decision, the French DPA approaches data protection law as a practical guide for WMS developers and managers in operating systems which fosters the workforce's well-being by leveraging the GDPR's framework. We suggest that, beyond the context-specific case of Amazon France and the French DPA, the GDPR and the forthcoming AI Regulation should play a more prominent role in the design and operation of WMS.

4. WMS through the lens of the GDPR and AI Regulation.

The WMS thus requires compliance with two key European regulations: the GDPR and, as we shall see in this section, the AI Regulation.[41] Both Regulations are directly applicable across the EU, and offer critical guidance on designing a WMS informed by data protection and human-centric AI principles that safeguard workers' fundamental rights. The AI Regulation, approved in 2024, will be fully effective in 2026. In Section 4.1, we discuss a few core principles and obligations arising from the GDPR for WMS deployers. We identify the principles and obligations that prevent excessive and unnecessary monitoring, in order to

[37] Molè M., nt. (3).
[38] Calzavara M., Persona A., Sgarbossa F., Visentin V., nt. (30); De Lombaert T., Braekers K., De Koster R., Ramaekers K., nt. (21).
[39] Molè M., *The Internet of Things and Artificial Intelligence as Workplace Supervisors: Explaining and Understanding the New Surveillance to Employees Beyond Art. 8 ECHR*, in *Italian Labour Law e-Journal*, 15, 2, 2022, 87-103.
[40] Marassi S., Bolte J., nt. (4).
[41] For an introduction on the application of the GDPR and AI Regulation on algorithmic management *see*: Abraha H., *Regulating algorithmic employment decisions through data protection law*, in *European Labour Law Journal*, 14, 2, 2023, 117–332; Guglielmetti M., *Automated work and workers' rights: platform work and AI work management systems*, in Ponce Del Castillo A. (ed.), *Artificial Intelligence, Labour and Society*, European Trade Union Institute, 2024, 127–140.

highlight data collection practices that enhance workers' well-being. Section 4.2 follows up with further obligations that will be applicable to WMS users from 2026, with particular reference to the Fundamental Rights Impact Assessment (Article 27 AI Regulation).

4.1. Principles and obligations for a WMS under the GDPR.

Any company/data controller wishing to install a WMS in its logistics operations shall justify its implementation according to one of the legal grounds enshrined by Article 6 GDPR ("Lawfulness of processing"). It is crucial for companies using a WMS to choose a valid legal basis for this processing, i.e. to identify a "justification" for their data processing, among the ones provided for by Article 6 GDPR. The most relevant legal basis for a WMS is Article 6(1)(f): "processing is necessary for the purposes of the legitimate interests pursued by the controller or by a third party". This legal ground is frequently employed by corporations (such as Amazon) within their warehouse operations for data collection and monitoring practices.[42] It allows organisations to process personal data if they have a legitimate interest that is not overridden by the interests or fundamental rights of the data subject.[43] Ensuring items are picked for timely shipment requires monitoring of picked items, for instance, can be considered a legitimate interest for a company operating in logistics. When using this legal basis, whoever implements a WMS needs to carry out a "balancing act" between their legitimate interests against the fundamental rights of the employees and relevant labour standards.[44] If the fundamental rights of the employees are found to be disproportionately affected by the data processing, then the legal basis will not be considered valid, as already happened for the WMS used by Amazon France.[45] This ultimately means that, if less intrusive ways (e.g. less data collected, shorter data retention, etc.) can be found to achieve the intended business objectives, then the processing is not lawful.[46]

Before delving into the relevant principles and obligations that an operating WMS has to comply with, it is important to discuss a generalised prohibition that we find in Article 9 of the GDPR. This Article discusses the processing of special categories of personal data; they include racial or ethnic origin, political opinions, religious or philosophical beliefs, health data and biometrics. It is important to bring forth this discussion, as some of the data processed by WMS could potentially involve this data category. They are often essential for improving well-being and encompass sociodemographic and anthropometric information about

[42] Molè M., nt. (3).
[43] Article 6(1)(f) GDPR.
[44] For a discussion of balancing diverse rights and interests, such social and economic ones: De Vries S.A., *Balancing Fundamental Rights with Economic Freedoms According to the European Court of Justice*, in *Utrecht Law Review*, 9, 1, 2013, 169.
[45] Molè M., nt. (3).
[46] Article 29 Data Protection Working Party, *Opinion 06/2014 on the notion of legitimate interests of the data controller under Article 7 of Directive 95/46/EC*, 2014, available at: https://ec.europa.eu/justice/article-29/documentation/opinion-recommendation/files/2014/wp217_en.pdf (accessed 30 October 2024).

workers, which can inform operational decisions.[47] Article 9 GDPR would seem to place a generalised ban on their collection. However, in paragraph 2, more specifically at point b), we read that "processing is necessary for the purposes of carrying out the obligations and exercising specific rights of the controller or of the data subject in the field of employment and social security and social protection law in so far as it is authorised by Union or Member State law or a collective agreement pursuant to Member State law". Article 9(2)(b), therefore, allows the processing of sensitive data if (and only in that instance) such information is needed to comply with labour standards, such, for instance, occupational health and safety (OSH).[48] This will be addressed further in Section 5, as we deem this exception useful when it comes to improving workers' rights and well-being.

Beyond establishing a legal basis under Article 6 GDPR and adhering to Article 9, data controllers using WMS must also comply with broader obligations under Articles 24 and 25 GDPR. Article 24 ("Responsibility of the controller") requires controllers to demonstrate compliance with the GDPR, reinforcing the principle of accountability by mandating proactive steps to uphold data processing principles. These steps include implementing the appropriate technical and organisational measures. Article 25 ("Data Protection by Design and by Default") further prescribes guidance on how to design and integrate these measures, emphasising practices like pseudonymisation and data minimisation. Data minimisation, which is defined in Article 5(1)(c) GDPR, requires that the WMS does not collect more data points than is actually required and for a reasonable retention period for the specific processing purpose.[49]

An in-depth discussion of all the principles of Article 5 cannot be undertaken here for space constraints, however it is useful and necessary to mention the principle of purpose and storage limitation (Articles 5(1)(b) and (d)). Purpose limitation requires that before implementing the WMS, the deployer shall establish (and notify to workers according to Article 13 GDPR) the specific and unique purposes for which the WMS will collect and process personal data.[50] For example, data collected by the WMS to improve ergonomics cannot be used for performance assessment if not specified in advance. The principle of purpose limitation is crucial in data protection law to prevent "function creep" - the

[47] Differences in workloads between male and female workers are calculated through these data. Research in OM shows that recognizing and addressing these differences can enhance the alignment of tasks with workers, leading to both ergonomic and performance benefits. See Section 3.1., in particular: Diefenbach H., Grosse E.H., Glock C.H., *Human-and-cost-centric storage assignment optimization in picker-to-parts warehouses*, in *European Journal of Operational Research*, 315, 3, 2024, 1049–1068; De Lombaert T., Braekers K., De Koster R., Ramaekers K., nt. (6).

[48] Using sensitive data (as defined by Article 9) is frequent in OSH, since most of Artificial Intelligence tools recently developed (e.g., AI cameras to prevent accidents on the factory floor) need that data to operate. They are all grounded on the exception provided by Article 9(2)(b). See: European Agency for Safety and Health at Work, *Smart Digital Monitoring Systems for Occupational Safety and Health: Opportunities and Challenges*, 2023, available at: https://osha.europa.eu/sites/default/files/Smart-digital-monitoring-systems-Opportunities-challenges_en.pdf (accessed 30 October 2024).

[49] Article 5(1)(c): personal data processed shall be "adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed". Amazon, e.g., was collecting more data than necessary and for excessively long data retention periods. *See*: Molè M., nt. (3).

[50] Article 29 Data Protection Working Party, *Opinion 3/2013 on purpose limitation*, 2013, available at: https://ec.europa.eu/justice/article-29/documentation/opinion-recommendation/files/2013/wp203_en.pdf (accessed 30 October 2024).

expansion of personal data use beyond the initial collection purposes.[51] Storage limitation is closely associated with data protection by default, thereby establishing a strong connection to Article 25(2) of the GDPR.[52] The Article stipulates that personal data should not be kept in a form that allows identification of the data subject for longer than is necessary for the purposes for which the data is processed. In the French case mentioned above, the DPA argued that the retention period of 31 days for the information regarding the execution of the tasks was disproportionate. A weekly retention period of these data was thought to suffice to achieve the legitimate business interests of Amazon.[53] This case illustrates that, if an employer wants to retain the data for longer periods, they must justify their decision, if not, the data has to be deleted or anonymised.

The last and most important of the obligations analysed here for a data controller implementing a WMS is the Data Protection Impact Assessment (DPIA) required by Article 35 GDPR. The DPIA aims to identify and mitigate risks before the data processing is put into operation on data subjects. Carrying out a DPIA is mandatory in certain circumstances, i.e. when the data processing is likely to result in a "high risk" to the rights and freedoms of natural persons, particularly when using new technologies.[54] Article 35(3)(a) states that a DPIA is mandatory where there is a systematic and extensive evaluation of personal aspects, which can produce legal effects concerning the natural person involved in the processing. Article 29 WP has further stressed that employees are particularly "vulnerable data subjects", thus making the DPIA necessary.[55] Lastly, it should not be overlooked that Recital 75 GDPR, which provides for interpretative guidelines for the DPIA, explicitly qualifies as a high-risk data processing "where personal aspects are evaluated, in particular analysing or predicting aspects concerning performance at work". This Recital, by explicitly framing data processing at work as a "high risk" one, further clarifies to data controllers of WMS that they must go through a DPIA.

WMS, ultimately, must undergo a DPIA prior to its implementation. Companies deploying them in warehouses shall perform such assessment according to Article 35(7) requirements, i.e. a systemic description of the potential risks associated with the operation of a WMS on workers and whether this represents a legitimate interest under Article 6(1)(f) GDPR; whether the implementation of the WMS is necessary for the business model and it disproportionately impacts workers' rights; finally, if any risk or threat is foreseen, which concrete and operational measures are needed to prevent them.

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[51] For an in-depth discussion: Koops B.J., *The concept of function creep*, in *Law, Innovation and Technology*, 13, 1, 2021, 29–56.

[52] Article 25(2) GDPR: That obligation applies to the amount of personal data collected, the extent of their processing, the period of their storage and their accessibility.

[53] Molè M., nt. (3).

[54] Article 35 GDPR: "Where a type of processing in particular using new technologies, and taking into account the nature, scope, context and purposes of the processing, is likely to result in a high risk to the rights and freedoms of natural persons, the controller shall, prior to the processing, carry out an assessment of the impact of the envisaged processing operations on the protection of personal data. [2]A single assessment may address a set of similar processing operations that present similar high risks".

[55] Article 29 Data Protection Working Party, *Guidelines on Data Protection Impact Assessment (DPIA)*, 2017.

4.2. AI Regulation and WMS.

The AI Regulation (EU Reg 2024/1689), which will be applicable in EU Member States gradually from 2025,[56] establishes principles and obligations for the safe and ethical use of AI. Article 3(1) AI Regulation defines AI system as

a machine-based system that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment, and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments.

A WMS, being able to infer future activities and provide instructions to workers for efficient warehouse processes, qualifies as an AI system.[57] Hence, in this analysis of the legal framework applicable to WMS, the AI Regulation must be taken into account.

The AI Regulation adopts a risk-based approach, categorising AI systems into four risk levels: unacceptable, high, limited, and minimal. More specifically, a WMS may qualify according to Article 6(2) and its reference to Annex III, paragraph 4, as a "high-risk" system due to its ability to make decisions affecting terms of work-related relationships, to allocate tasks based on individual behaviour or personal traits, and evaluate the performance and behaviour of workers. This means that the development and implementation of WMS shall follow the requirements provided for by Chapter III in Articles 8-15 (High risk AI systems). Among the main requirements, Article 13 provides that deployers of AI systems - i.e. employers who purchase WMS from providers - must be put in a position of properly understanding and operating them correctly. In other words, the warehouse manager should be able to fully understand and control the operation of a WMS, especially when potential threats from its operation arise for the workforce. Article 14 in this regard provides that the AI systems should enable employers to understand its capabilities and limitations, detect and address issues, avoid over-reliance, interpret its output, and decide whether to use or halt its operation.[58]

The information received pursuant Articles 13 and 14 is relevant for employers operating WMS, since they are required to conduct a Fundamental Rights Impact Assessment (FRIA, Article 27), which can incorporate the results of any prior DPIA carried out (Article 35 GDPR). Recital 57 specifies that the FRIA is essential since some risks may not be anticipated during development from providers. Drafting a FRIA, like the DPIA, requires to specify the work process to which the WMS will be applied (logistics in warehouses with human workers), the duration, the involved employees (warehouse workers), the fundamental rights involved at risk (e.g., the right to privacy, freedom of expression, health and safety at work…), and the measures to prevent such potential harms. They must collaborate with

[56] For a timeline of the application 2025-2026: Future of Life Institute, *Timeline of key dates,* available at: https://artificialintelligenceact.eu/implementation-timeline/ (accessed 30 October 2024).
[57] *See:* Section 2.
[58] Article 14(4)(d) provides that employers-deployers of WMS can override the system's decisions through what the Regulation broadly defines as a 'stop button'.

relevant stakeholders, including providers and worker representatives (Recital 92),[59] as well as affected groups and experts, and notify market surveillance authorities after completing assessments (Article 26(5) and Article 27(3)). Article 27 further clarifies that if any FRIA obligations are already met through the DPIA, employers can rely on those assessments.

We further identify in Article 60 AI Regulation a legal and practical tool to test the functionalities of WMS, although this procedure remains optional. Article 60 details the guidelines for testing high-risk AI systems in real-world environments before they are sold to companies or individuals. Companies intending to implement a WMS can submit their testing plans to the relevant authority in the EU member state where the testing will be carried out - the relevant Authorities will be determined in the coming years according to the implementation plan of the AI Regulation.[60] WMS developers must ensure that the testing does not pose risks to vulnerable groups and that any data collected is securely protected. Should any serious incidents occur, they must be reported immediately, and the testing must be halted until the issues are addressed. According to Article 60(4)(j) and (k), (j) the oversight of testing in real-world conditions is managed by the WMS provider, and it shall be carried out by individuals who are appropriately qualified and possess the necessary capacity, training, and authority to execute their responsibilities effectively. This ensures that all aspects of the testing process are monitored and managed by experts who can address any well-being issues that may arise from pressing and intrusive monitoring of warehouse workers.[61] Having examined the most pertinent GDPR and AI Act articles, the following section aims to guide, through practical case studies, how these legal provisions and principles can be leveraged to enhance workers' well-being.

5. Bridging the gap: promoting workers' well-being through the GDPR and AI Regulation.

Thus far, we have explored the core principles of a legitimate WMS under the GDPR and AI Regulation. These come as obligations (except for Article 60 AI Regulation) for companies deploying WMS. In this section, we go beyond a mere "compliance-check" for WMS, and we introduce three innovative studies exploring the use of personal data in operations to improve efficiency and/or worker well-being, which are not yet tested through the lens of GDPR and AI Regulation. By analysing them, we showcase that there is a balance to be struck between monitoring and algorithmic management, and well-being improvements. This section provides valuable guidance to both practitioners as well as

[59] Recital 92, AI Regulation: "This Regulation is without prejudice to obligations for employers to inform or to inform and consult workers or their representatives under Union or national law and practice, including directive 2002/14/EC on a general framework for informing and consulting employees, on decisions to put into service or use AI systems".
[60] Council of the European Union, *Timeline - Artificial intelligence*, 2024, available at: https://www.consilium.europa.eu/en/policies/artificial-intelligence/timeline-artificial-intelligence/ (accessed 30 October 2024).
[61] These paragraphs of Article 60 mirror the "Human oversight" principle mandated by Article 14 AI Regulation. *See*: Section 4.2.

researchers on if and how personal data can be managed to improve well-being, whilst ensuring GDPR and AI Regulation compliance.

5.1. Case 1: Picker whereabouts in the dynamic (re-)routing of pickers.

Van der Gaast, Jargalsaikhan and Roodbergen propose a new type of order assignment in which the WMS dynamically updates original order assignments as customer orders arrive. This new policy dynamically (re-)optimises all outstanding picking tours, requiring knowledge of the pickers' locations and task completion times.[62] Building on their research, we recommend two possible approaches to implement under the GDPR and AI Regulation. The first one requires the involvement of the DPIA (Article 35 GDPR) and FRIA (Article 27 AI Regulation), while the other one involves the real-world testing conditions of AI systems (Article 60 AI Regulation).

The first approach still involves the identification of individuals' location and *personal assignment:* this means that according to Article 4(1) GDPR workers would be identifiable, and therefore, data protection rules apply. Fed by data obtained through technological devices such as pick-by-voice systems or scanners, the WMS will associate tasks and locations with individual pickers. This involves personal data which are continuously generated by the system and its technologies. At the same time, such a data collection format enables performance evaluations, idle time analyses, and more. The advantage of this approach is that warehouses can achieve greater efficiency, but the impact on worker well-being is not necessarily apparent. The downside of this approach, evidently, is still potential misuse of personal data for unapproved/illegitimate purposes and an insufficient workload reduction for order pickers. We therefore recommend that prior to the implementation of a WMS with location tracking, the company should carry out a joint DPIA and FRIA over the implementation of the system. As seen, that assessment is mandatory in instances of workplace surveillance[63] and requires the consultation of workers representatives according to Article 35(9) GDPR. During the draft of the DPIA, according to Article 35(7)(d), we recommend that developers, deployers, and workers agree on those "measures envisaged to address the risks". Building on the German experience of works council codetermination, those measures should include a "probation period" where the WMS is fully deployed, but after a certain period (for instance, 60 days), the parties meet again to refine the operationalisation of the system in order to hear and receive feedback from workers on the (perceived) workload and possible ameliorations on the WMS operation.[64]

[62] van der Gaast J.P., Jargalsaikhan B., Roodbergen K., *Dynamic Batching for Order Picking in Warehouses*, in *Progress in Material Handling Research*, 2018.
[63] *See:* Sections 4.1. and 4.2.
[64] On the German experience *see*: Adams Z., Wenckebach J., *Collective regulation of algorithmic management*, in *European Labour Law Journal*, 14, 2, 2023, 211–229; Rolf S., *AI and Algorithmic Management in European Services Sectors: Prevalence, functions and a guide for negotiators*, Friedrich-Ebert-Stiftung – Competence Centre on the Future of Work, Brussels, 2024, available at: https://library.fes.de/pdf-files/bueros/bruessel/21073.pdf.

The second approach relating to picker (re-)routing and its data implications can be built upon an *anonymous assignment.* In this instance, the collected data are systemic.[65] The WMS would not recognise workers through personal data, but only data points generated by, for example, scanners. This means that the assignment of scanners to workers is completely anonymous, i.e., one cannot trace it back to any individual. At the same time, the status of completion of orders can still be monitored in fine detail and interventions can be made if necessary to ensure timely shipments. While this hampers individual performance assessments, the objective of enhancing warehouse efficiency can still be achieved. Furthermore, the overall performance of a group of workers can be measured and assessed through aggregated data. This approach is advised by the French DPA in the sanction to Amazon France.[66] The DPA, in its decision, stresses how "collective evaluation of efficiency" fits well with the overall goal of warehouses to deliver a large volume of orders in short periods of time - as there would be no strict necessity to know with excessive granularity the efficiency of each worker but of the collective. More specifically, the DPA in that case advised to retain employees' data for shorter periods (Amazon was retaining individual data for a month). According to the French Authority, after a few days data should be anonymised as there is no legitimate interest, e.g. one-to-one feedback sessions, to store such wealth of granular data for longer periods. If complete anonymisation is enacted, the GDPR would not be applicable. If anonymisation is done after a few days, the GDPR will apply until the aggregation of data occurs.[67]

Since the WMS still qualifies as an AI system, we recommend that the complete anonymisation of scanner assignment (whether enhanced by default or after a few days) is tested through Article 60 AI Regulation (Testing of AI systems in real-world conditions). This way, the WMS goes under an "anonymisation check" before it is put into operation in companies.

5.2. Case 2: Picker ergonomics and efficiency in various pallet configurations.

The study by Hanson, Medbo, Berlin and Hansson focuses on determining how physical workload and picking time vary when workers pick items from large containers.[68] The research considers two main variables: the location of the component within the container and whether the pallet is tilted. Additionally, the study examines the influence of pickers' height on these factors. The dual focus on well-being, in particular ergonomics, and efficiency makes this research particularly relevant for optimising the WMS. The methodology used involves a controlled experiment conducted in a real-world setting, closely emulating actual warehouse conditions. This approach allows for the collection of data that is highly

[65] *See:* Section 3.
[66] Molè M., nt. (3).
[67] Marassi S., Bolte J., nt. (4).
[68] Hanson R., Medbo L., Berlin C., Hansson J., *Manual picking from flat and tilted pallet containers*, in *International Journal of Industrial Ergonomics*, 64, 2018, 199–212.

representative of real-world scenarios while maintaining the structure of an experiment for more controlled observations.

Two types of picker-related data are considered in the analyses: the height and gender of pickers. According to Section 3, they are classified as personal data. Height data, more specifically, help to distinguish between tall and short pickers, and relate their picking behaviour to the item location (e.g., bottom pick vs. top pick). Gender data, although collected by the researchers, did not play a prominent role in the experiment's results.

The study proceeds to record picker behaviour in relation to item locations. More specifically, this aspect of the study involves observing how pickers approach picking locations and their ergonomic postures. This is useful for analysis within the experimental context, but poses legal challenges for continuous monitoring in real-world settings. Collecting such data to optimise the ergonomics of picking is lawful, and these recordings might also be used for training purposes in real-world settings, such as ergonomic training sessions. However, in light of the French DPA's recent findings, we emphasise the importance of shorter data retention periods in relation to the operationalisation of a WMS which upholds well-being as a critical objective. The DPA in fact held Amazon France accountable for not respecting the data minimisation principle under Article 5(1)(c) GDPR. Following the sanction, Amazon reduced the period from 31 days to 7 days.[69] In other words, collecting such data for optimising the ergonomics of picking is lawful, but being a continuous monitoring of workers, those principles of the GDPR listed in Article 5(1) make sure that the WMS does not collect extensive datasets about workers for unreasonable periods of time.

Furthermore, the Authors themselves raise an important legal consideration on how to use worker height data to assign picking tasks. They reference a precedent Court case in Sweden where an automotive manufacturer was found guilty of indirect discrimination for denying employment to a short female applicant based on height, citing ergonomic risk. The Court ruled this criterion systematically discriminated against female applicants, despite being framed as a gender-neutral (occupational health and safety) concern.[70] Therefore, instead of imposing physical criteria, the study suggests designing the workplace not according to an "ideal picker" but according to a diverse and variegated workforce so as to accommodate different ergonomic principles aimed at improving well-being and system performance.[71] The study of Hanson et al. shows that on recruitment policies and on OSH policies, the collection of personal data proves to be beneficial in fostering a diverse workforce with high health and safety standards.

In general, we recommend that WMS shall collect only data that are essential to reach predetermined goals, adhering to GDPR's minimisation principle (Article 5(1)(c)). For instance, Hanson et al. in their study collected gender data, even though this variable was not integrated into the analyses. If a WMS operates under a similar setting and additionally collects data, for example, on one's age and weight without a valid reason, it might conflict with the principles of minimisation and privacy by design and by default principles (Article

[69] Marassi S., Bolte J., nt. (4).
[70] Hanson R., Medbo L., Berlin C., Hansson J., n. (68), 210.
[71] Hanson R., Medbo L., Berlin C., Hansson J., *ibidem,* 211.

25 GDPR). In those cases, gender data, as well as age and weight data, would not be compliant with the legal ground of legitimate interest to operate a warehouse (Article 6(1)(f)): processing these data is not justifiable from a technical point of view. Height data, instead, represent a legitimate interest for data collection since their processing can allow for a diverse recruitment process and improve the ergonomic benefits by allowing WMS to distribute orders to the picker with the right height according to safety standards.[72]

Also, in this option, we recommend WMS developers, before putting their system on the market, to apply for the Article 60 AI Regulation procedure on real-life testing conditions. Furthermore, a DPIA and FRIA test is also desired. By making use of these legal tools, WMS users can verify these findings in circumscribed scenarios, and further assure a high level of protection to the employees.

5.3. Case 3: Picker heart rate for evaluating a system with picker participation.

The previous two cases present some critical points of attention WMS developers and warehouse managers should pay close attention to in the light of WMS deployment. However, one could argue that the data collection in those two cases remains relatively non-invasive. That is, data are collected through technologies that do not require close physical interaction with human workers. In pursuit of more accurate physiological data for increased planning efficacy, increasingly more studies in operations management resort to more invasive data collection methods, e.g. eye tracking[73] or heart rate monitoring.[74] Although their omnipresence in real-world environments seems far-reaching, tools for collecting workers' heart rate, temperature, fatigue level etc. are already used in some workplaces.[75] The third case we discuss pertains to heart rate monitoring in an experimental context. The adopted tools in the study are markedly less invasive compared to advanced measuring tools available in the market. Additionally, the monitoring duration in the study is limited, making the study a 'light' version of some real-world data collection practices. However, it serves as a good starting point to initiate the discussion on how even more sensitive data can be used in relation to WMS deployment.

In particular, De Lombaert, Braekers, De Koster and Ramaekers investigate the potential impact of a work system where warehouse workers can choose their next order.[76] The study

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[72] Although top-down task assignments aimed at improving ergonomics are increasingly common in warehouse (and operations management) literature, e.g. Calzavara M., Persona A., Sgarbossa F., Visentin V., nt. (30), recent literature argues that more autonomy should be granted to order pickers themselves to, for example, be able to include more variation in their workdays De Lombaert T., Braekers K., De Koster R., Ramaekers K., *Is it good to have a choice? The value of participatory order assignments in warehousing*, in *International Journal of Operations & Production Management*, 2024. We refer to De Lombaert T., Braekers K., De Koster R., Ramaekers K., nt. (21), for more insights on how those participatory systems interfere with ergonomics.

[73] Zheng T., Glock C.H., Grosse E.H., *Opportunities for using eye tracking technology in manufacturing and logistics: Systematic literature review and research agenda*, in *Computers & Industrial Engineering*, 171, 2022, 108444.

[74] De Lombaert T., Braekers K., De Koster R., Ramaekers K., nt. (72).

[75] Bodytrack, *Fatigue Monitoring Systems*, available at: https://bodytrak.co/fatigue-monitoring-wearable-systems/ (accessed 30 October 2024).

[76] De Lombaert T., Braekers K., De Koster R., Ramaekers K., nt. (72).

examines how this system affects performance and picker well-being, both psychological and physical. Specifically for the physical aspect, the Authors use data tracked by heart rate monitors, which qualifies as sensitive data under Article 9 GDPR, as a proxy for fatigue, providing insights into the physical demands placed on workers. The study is conducted as a long-term (six weeks) field experiment in a real-world warehouse setting. Participation was voluntary, with workers signing informed consent forms. This ensured that only those willing to participate were included, and there was no coercion from the employer to sign these forms.

Heart rate monitoring is a very invasive form of data collection that needs to find a justification under Article 9 GDPR. To minimise invasiveness, the study used wristwatches instead of more accurate but considerably more intrusive heart rate belts. The data collected allowed the Authors to perform regression analyses, controlling for factors like gender and height. These control variables are crucial in statistical analyses to account for factors that might influence heart rate independently. By means of Article 9(2)(b) GDPR, which justifies the recourse to sensitive data only to comply with relevant labour standards, we find a confirmation of the interesting legal analysis proposed by Van Bekkum and Borgesius.[77] By allowing, under conditions of strict necessity, to train and test WMS through workers' sensitive data, researchers can develop accurate and less discriminatory models to run the order fulfilment process.[78] And, ultimately, allowing companies using WMS to collect and process only the right amount of data without disproportionately reducing workers' rights.

As in Hanson et al., during testing, certain collected data were left unused for the assessment of accurate WMS functionalities.[79] In the study of De Lombaert et al., pickers' weight was collected but eventually not used in the analyses.[80] Although these data were initially collected with good intentions as a proxy of picker body size, ultimately the authors chose to conceptualise the latter with height data, which leads us to argue that collecting picker weight was in fact not compliant with the principle of data minimisation (Article 5(1)(c)). Generally, this shows that researchers, during their experimental design phase, should thoroughly contemplate which data to collect and provide clear justification for it, for example during ethical committee reviews. Equally evident is that the collection of data, which academic studies prove to be insignificant for improving well-being and/or efficiency, is difficult to substantiate from an operational point of view, as it reaches beyond the legitimate interest stipulated in Article 6(1)(f). In that context, the testing of data collection legitimacy presents an exciting research opportunity, potentially realised through close collaborations between academia and industry.

It is noteworthy to recognise that in this study heart rate monitors were used solely for evaluative purposes, not for continuous monitoring or decision-making within the WMS. The Authors stress that their goal was to test the effectiveness of the intervention, not to implement long-term monitoring. The heart rate data was crucial in making a case to the

[77] Van Bekkum M., Zuiderveen Borgesius F., *Using sensitive data to prevent discrimination by artificial intelligence: Does the GDPR need a new exception?*, in *Computer Law & Security Review*, 48, 2023, 105770.
[78] Van Bekkum M., Zuiderveen Borgesius F., *ibidem*.
[79] Hanson R., Medbo L., Berlin C., Hansson J., nt. (68).
[80] De Lombaert T., Braekers K., De Koster R., Ramaekers K., nt. (72).

company's management for the permanent implementation of the proposed system. Once the experiment concluded, heart rate monitoring ceased, respecting legitimate interests and the data minimisation principle. However, it could be that the management introduces continuous heart rate monitoring if they want the WMS to propose orders to pickers which respond to their physical fitness in an ad hoc manner. Despite understandable scepticism regarding the use of sensitive data in employment contexts, we contend that research in operations management and warehousing workers' well-being can benefit from leveraging these exceptions to build comprehensive well-being constructs, as previously developed by Van Bekkum and Borgesius.[81] Thus, from the perspective of scientific management, very sensitive data can be measured to evaluate the effectiveness of different policies, but continuous monitoring is not necessary once the policy is validated to be (in)effective. Article 60 of the recently approved AI Regulation could serve as a valuable legal and practical framework for applying the methodologies developed by De Lombaert et al.. Additionally, Article 61 of the AI Regulation provides crucial safeguards for collecting workers' sensitive data: workers participating in these pre-market WMS tests must provide informed consent before engaging in real-world AI testing scenarios. They need to be fully aware of the specifics of the test, including its duration and any potential inconveniences. Moreover, they should be informed of their rights, such as the ability to refuse or withdraw from the test at any time without facing any repercussions. This approach ensures that the collection and use of sensitive data are conducted ethically and transparently, balancing the potential benefits of improved worker well-being, protection of individual privacy, and fostering innovation of AI systems (and WMS). The participants in the discussed study all signed informed consent.

6. Conclusions.

This paper introduces an interdisciplinary study that addresses legal- and well-being-related concerns surrounding the rise of technology-intensive warehouses, such as those operated by Amazon. While the introduction of technologies in these settings is often criticised for prioritising efficiency at the expense of working conditions, this research takes a different approach. It brings together insights from warehouse design, data protection, and labour law to explore how, as seen in the case of Amazon France, the correct application of data protection principles in the design of WMS can foster both operational efficiency and worker well-being.

In this paper, we first outline the critical role the WMS plays in today's warehouses, coordinating tasks and managing the accurate fulfilment of customer orders. The data which are required for its effective operationalisations are discussed in Section 3. In that section, we discuss data collection through an operations lens and then gradually shifts to a legal perspective, setting the stage for a detailed discussion of the key regulations governing WMS – namely, the GDPR and the AI Act. While Section 4 provides a comprehensive examination of the pertinent legal standards from both Regulations, Section 5 goes beyond and bridges

[81] Van Bekkum M., Zuiderveen Borgesius F., nt. (77).

the gap between compliance with GDPR and AI regulations and the enhancement of workers' well-being in WMS operationalisation. Three state-of-the-art studies in the warehousing field are discussed, as well as the potential (non-)compliance of their WMS operationalisation with GDPR and AI regulations and its implications for worker well-being. These studies clearly demonstrate how the collection of personal data has the potential to enhance worker well-being (e.g., through preventing fatigue or improving ergonomic postures), while unnecessary and inappropriately purposed data collection – such as in the case of Amazon France – can result in, for example, punitive measures and violations of privacy rights. Notable design principles which WMS developers and deployers should uphold to favour the latter over the former are data minimisation, anonymisation, and pre-implementation testing. If these principles are adequately pursued, warehousing through mass collection of personal data could actually foster workers' well-being. Furthermore, we would like to underscore the significance of intensifying the connection between warehousing and legal scholarship to develop a WMS that can build on personal data collection not solely for faster and more efficient logistics, but also for the protection of workers' well-being and rights.

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