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# DECENTRALIZED WORKER-CENTRED OCCUPATIONAL MANAGEMENT IN HEALTH CARE: NATIONWIDE SURVEY AND ALPHA TESTING

S. Barrit[1,2,3,4], S. Abene[5], A. de Froidmont[6], J. André[7], S. El Hadwe[8], M. Al Barajraj[9] et A. Niset[3,4,10]

[1]*Neurochirurgie, Université Libre de Bruxelles, 1050 Brussels, Belgium*
[2]*Sciences Chirurgicales, Université Paris-Est Créteil, 94010 Créteil, France*
[3]*Sciense, New York, NY 10013, USA*
[4]*Délégation des Médecins Francophones en Formation asbl, 1390 Grez-Doiceau, Belgium*
[5]*Anesthésie-Réanimation, Cliniques Universitaires Saint-Luc, 1200 Brussels, Belgium*
[6]*Oncologie Médicale, Centre Hospitalier Universitaire de Liège, 4000 Liège, Belgium*
[7]*Radiologie, Hôpital Erasme ULB, 1070 Brussels, Belgium*
[8]*Department of Clinical Neurosciences, University of Cambridge, Cambridge, CB2 1TN, UK*
[9]*Department of Neurosurgery, University Hospital of Lausanne (CHUV), Vaud, Switzerland*
[10]*Médecine d'Urgence, Université Catholique de Louvain, 1348 Louvain-la-Neuve, Belgium*

**KEYWORDS :** quality of care ; artificial intelligence ; delivery of health care ; feedback ; health personnel ; job satisfaction ; perception ; personal satisfaction ; persistence ; health care systems ; medical residencies ; descriptive statistics ; management procedures ; occupational stress ; mobile applications ; employer ; verification ; transparency ; administrative burdens ; blockchain ; working conditions

**ABSTRACT**

**Background :** Occupational stress among healthcare workers negatively impacts job satisfaction and patient care quality, jeopardizing healthcare system sustainability. Traditional employer-driven approaches often fail to address these challenges comprehensively, leading to persistent gaps in work condition transparency and well-being.

**Aims :** To elucidate the working conditions of health workers and introduce a worker-centred, technology-based strategy moving beyond traditional practices and entrenched medical culture.

**Methods :** A nationwide survey of Belgian medical residents evaluated occupational conditions and perceptions of management practices. Additionally, the alpha version of a decentralized mobile application was tested to gather user satisfaction and feedback on its usability. The data were surveyed using Pearson's chi-squared and Kruskal–Wallis rank sum tests to assess associations between categorical and ordinal variables, respectively. Alpha-testing results were evaluated using descriptive statistics.

**Results :** The nationwide survey, involving 257 participants, revealed significant associations between medical specialty, work choices and compensation. Notably, 91% of participants expressed strong interest in our proposed open, decentralized solution. In the alpha testing phase, 12 testers reported high satisfaction regarding time-tracking accuracy and payroll verification, though challenges related to administrative burden were also identified.

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**Conclusions :** The findings underscore the need for innovative, worker-centred occupational management solutions. The proposed solution shows promise in improving autonomy and transparency, potentially enhancing healthcare delivery and sustainability.

**KEY LEARNING POINTS**

**What is already known on this subject :**

- Occupational stress in healthcare workers, particularly medical residents, is linked to inadequate working conditions, job dissatisfaction and compromised patient care.
- Existing employer-driven time-tracking and management systems often lack transparency, fail to account for extra hours and increase administrative burdens.
- Legal frameworks like the European Working Time Directive have shown limited effectiveness in addressing these challenges due to socio-cultural pressures and inadequate enforcement mechanisms.

**What this study adds :**

- A nationwide survey of 257 Belgian healthcare workers revealed 68% dissatisfaction with extra-hours tracking and 91% interest in an open, decentralized solution for occupational management.
- Based on these findings, a worker-centred solution was developed to address the main challenges identified.
- Alpha testing with 12 participants showed high user satisfaction with reporting accuracy and payroll transparency, though administrative burden remained a concern.

**What impact this may have on practice or policy :**

- The decentralized, open system enhances transparency in worktime tracking and compensation, directly addressing institutional norms and cultural pressures.
- By giving healthcare workers control over their data, the solution fosters accountability, informing public opinion through a data-driven approach and potentially driving policy reforms that promote regulatory compliance and a more equitable, worker-centred healthcare environment.

# Introduction

Work-related stress is a pervasive public health issue [1] linked to inadequate working conditions due to structural failures [2,3]. Healthcare workers are especially vulnerable, commonly facing resource-constrained [4] and crisis-ridden settings [5] with the intrinsic burdens of caregiving [6]. Primary missions such as caring, education and research are often impeded by cost-cutting measures that reduce supportive resources and the increasing administrative burden from medical liability documentation [7–9].

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These resource-capacity mismatches result in work overload [10], job dissatisfaction [11], and work–life imbalance [12], which not only affects the health workers themselves but also directly impacts patient care quality and outcomes. Individually, these issues contribute to severe health outcomes like burnout, depression and cardiovascular diseases [13–15]. Collectively, they compromise patient safety [16] and contribute to healthcare staff attrition [17], thereby threatening the sustainability of healthcare systems [18]. Research has demonstrated that healthcare worker stress is associated with increased medical errors [19], diminished patient satisfaction [20] and longer patient recovery times [21].

Various initiatives, including the European Union's European Working Time Directive (EWTD) [22] and the Occupational Safety and Health Act [23], have aimed to address these challenges. However, these legal frameworks have shown limited impact [24–26], partly due to inadequate working time recording systems [27] and the prevailing medical culture [28]. These employer-driven solutions focus on rostering and neglect the accurate activity tracking and well-being monitoring of healthcare workers. Moreover, these records are susceptible to opaque management and manipulation—as in unilateral alteration of records from the employer, as they are particularly exposed to peer, hierarchical and socio-cultural pressures [29].

Our proposed occupational management solution integrates multimodal and multisource data provided by health workers, employers, or an approved third party (Table 1). Data can be fixed attributes set periodically, such as (i.e. gross hourly wage) or opt-out status, or dynamic, encompassing real-time tracking data paired with collective insights. Timing inputs can be entered either synchronously or asynchronously relative to the tracked event, as either a schedule or record.

**Table 1.** Examples of timing input modalities with their features

| | **Provider** | **Timing** | **User friction**[a] | **Resilience**[b] | **Infrastructure** |
|---|---|---|---|---|---|
| **Manual completion** | Worker or employer | Async | High | Low | Low |
| **Badging** | Worker | Sync | Mid | Mid to high | Mid to high |
| **Digital log** | Worker | Sync | Low to mid | Mid | Low to mid |
| **Geofencing smart contact tracing** | Process | Sync | Low | High | Low to mid |

[a]User friction describes the degree to which a common workflow is considered difficult, time-consuming, or irritating for a user to complete. [b]Resilience is the potential ability to withstand internal and external influences.

These inputs fall under distinct, predefined states such as 'at work', 'available', or 'on leave'. These states can be further refined using indicators such as labels (predefined standardized sub-options tailored for collective needs, e.g. 'care', 'education', 'administrative') or tags (freeform keywords for personal needs). Additionally, indicators include sporadic event tracking, which can be user-driven (e.g. incident reporting) or solution-driven (e.g. mood monitoring).

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Data processing occurs within a multi-layered approach, where the health worker retains control and validates the processed data for a specific period. Once validated, a blockchain-based transaction is recorded in an open ledger, ensuring the immutability of the validated data with smart contract abilities (Figure 1). Blockchain refers to a decentralized digital ledger that records transactions in a way that is secure, transparent and resistant to tampering [30]. Herein, we use this technology to ensure the immutability and security of occupational data.

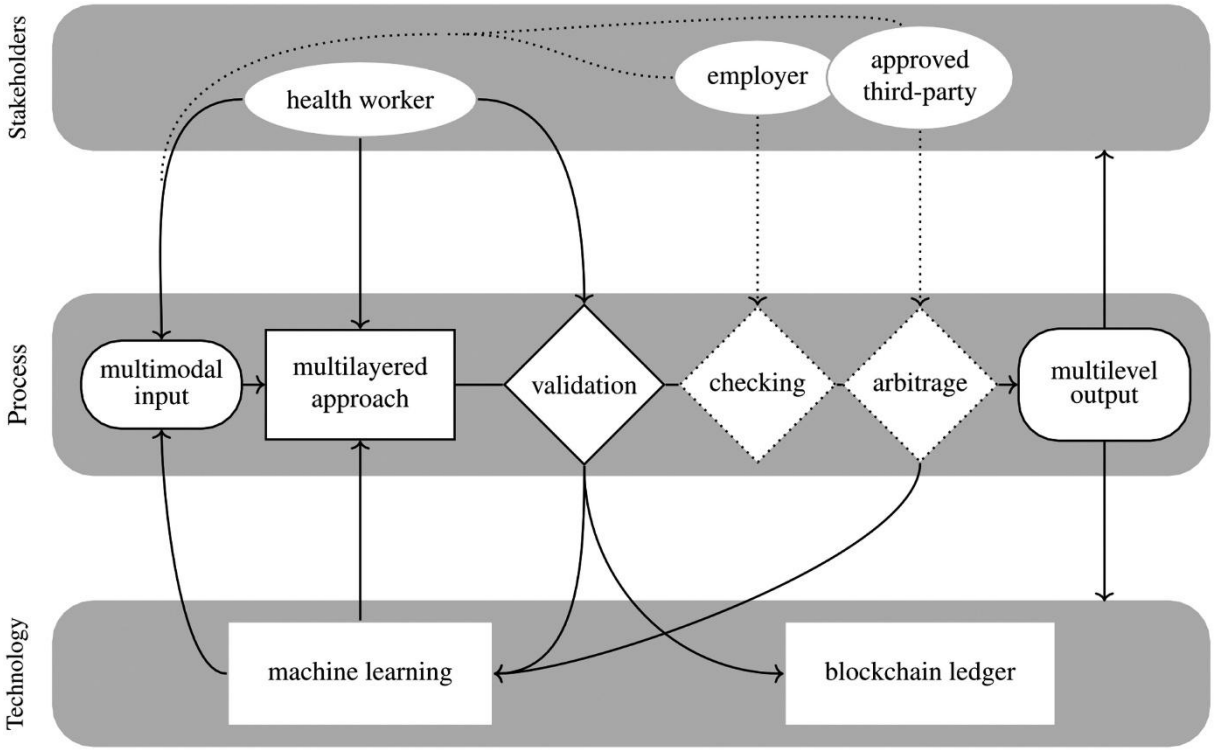


**Figure 1.** The conceptual framework.

This approach integrates various layers of timing data such as schedules, time tracking and records, along with complementary indicators (Figure 2). These layers act as safety nets for missing information and can be tailored or deemed obligatory in accordance with specific needs or legal requirements. Feedback loops continuously enhance data processing through machine intelligence.

To address conflicting information between these layers, the solution offers automated resolution mechanisms (Figure 3). Health workers are able to review and validate their time recordings punctually. They can optionally place validated recordings on hold for an approval period, allowing employers or authorized third parties to review them. For unresolved disputes, any pending litigations are described in the final report, which is then securely and immutably recorded on the blockchain.

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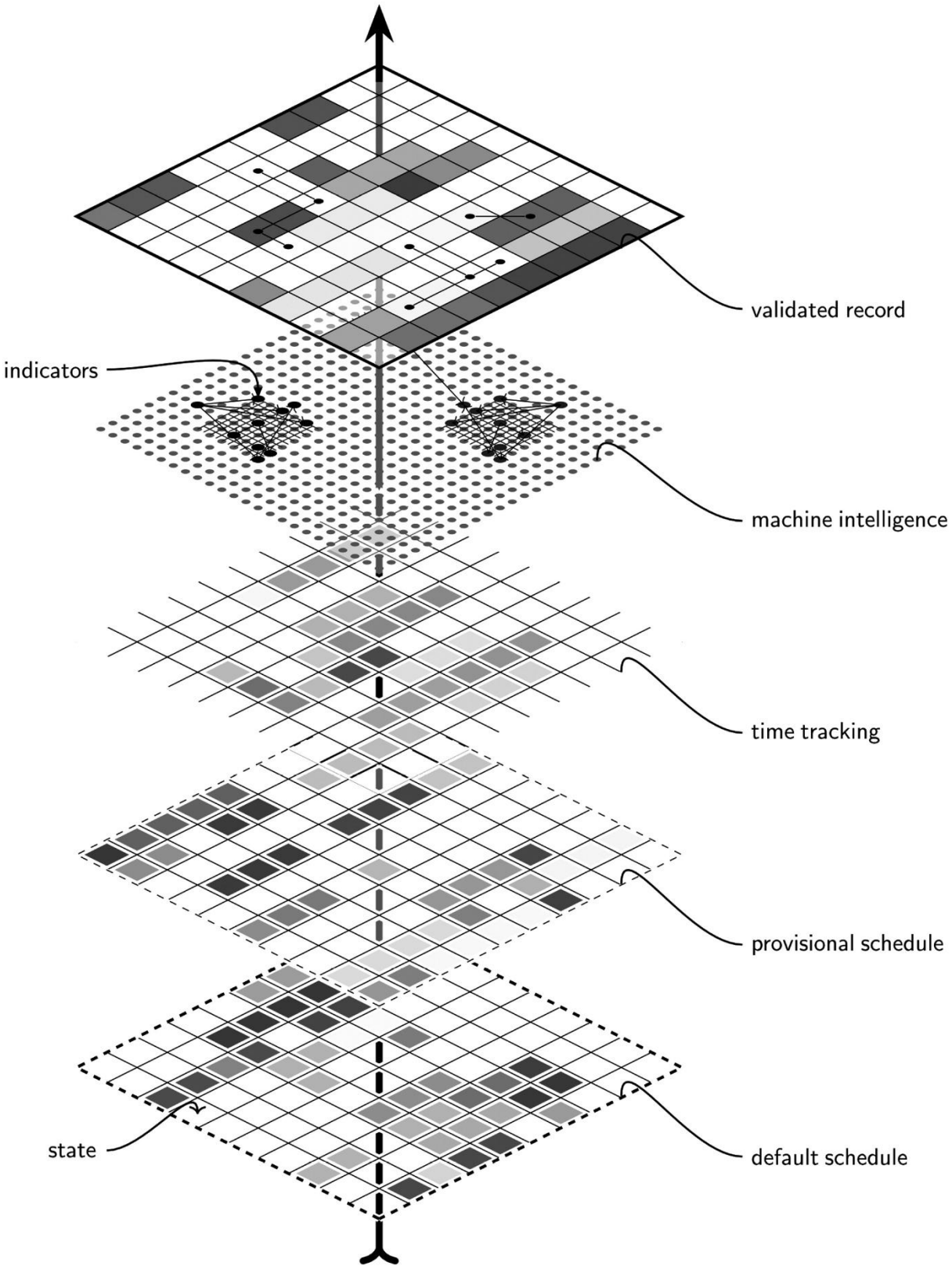


**Figure 2.** The multi-layered approach for multimodal data integration enhanced by machine intelligence.

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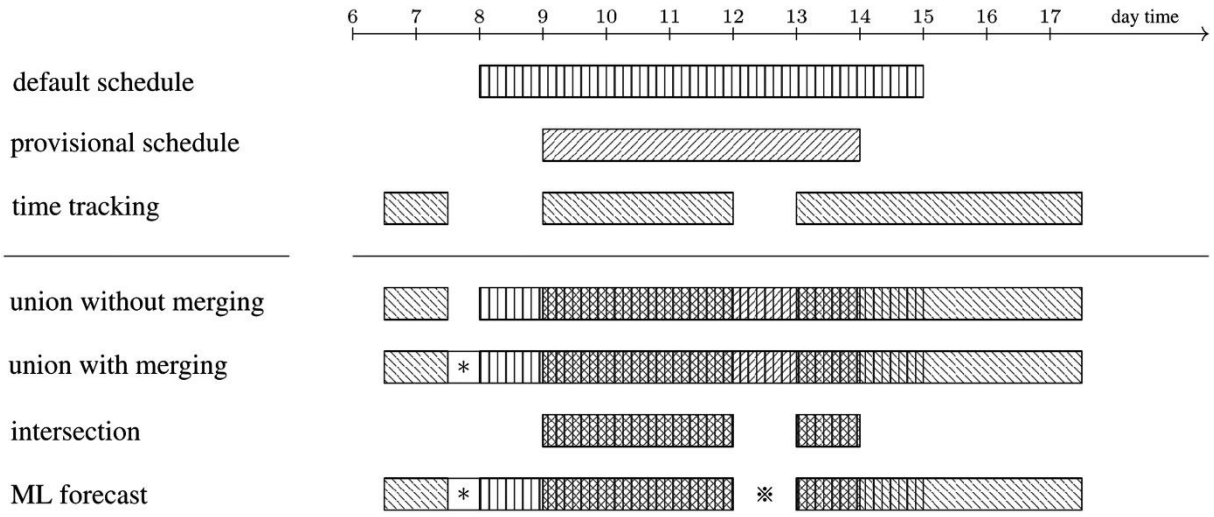


**Figure 3.** Examples of timing conflict resolution approaches. Various methods to resolve conflicts in recorded working hours. First section: multimodal inputs for time tracking. Default schedule—initial standard working hours; provisional schedule—hours planned by the department; time tracking—actual recorded working hours via the app. Second section: timing conflict resolution approaches. Union without merging—a composite of default, scheduled and tracked times without merging overlaps. Union with merging—unifies overlapping periods into a single block, indicated by an asterisk (*), suggesting some worked hours may have been untracked. Intersection—shows only overlapping time between the default schedule and time tracking. ML forecast—machine learning-based prediction of working hours, extrapolating from past data and patterns to anticipate specific events, such as lunch break (※).

At the individual level, a dashboard displays time tracking, wage estimates, occupational safety, health monitoring and legal compliance metrics. Users can generate on-demand static reports to summarize validated data for a specified period, and automated email reports are also available. At the collective level, the solution provides overview reports based on geographic or organizational criteria, such as institutional, local or global levels. These collective reports are openly accessible on a dedicated platform for all stakeholders and the public. Examples of insights, metrics, indices and alerts of interest are provided in the Table 1 (available as Supplementary data at *Occupational Medicine* online).

A decentralized autonomous organization (DAO) distributes governance, allowing stakeholders to participate equitably in decision-making and oversight. SubDAOs, functioning as independent entities within the larger organization, focus on specific endeavours. These may include feature development, technological enhancement, solution maintenance and security monitoring. Additionally, local stakeholders can organize daily operations, dispute resolution, policy-making and request customizations to meet their needs. An example of the DAO-subDAO structure for collaborative yet independent working groups is provided in Figure 1 (available as Supplementary data at *Occupational Medicine* online).

The solution adheres to common data protection regulations such as the General Data Protection Regulation (GDPR) and the California Consumer Privacy Act. Privacy and security are ensured through rigorous data minimization measures, pseudonymization, end-to-end encryption and multi-factor authentication. All data-sharing endeavours require explicit user consent.

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The technological stack utilizes open-source tools within a decentralized framework. Machine intelligence is harnessed through recurrent and convolutional neural networks, which are essential for tasks such as work schedule planning, well-being monitoring and anomaly detection. Federated learning is employed to maintain user privacy, enabling global model training without sharing raw, identifiable data. Further technical details are available in the solution's white paper.

Therefore, we introduce an AI-driven, open, decentralized and worker-centred solution for occupational management in health care. To validate our approach, we performed an in-depth analysis with Belgian medical residents. A group navigating dual roles as employees and students with intersecting clinical and academic duties. This position results in conflicts of interest among their employers and supervisors (i.e. legislation-pressure, economical pressure or ensuring care continuum, whilst having to provide adequate supervision, work–life balance, ensuring safety and well-being of their residents), which, in turn, subjects residents to vulnerabilities, notably coercion affecting career progression and academic achievement.

# Methods

We initiated a two-phase process to establish the need and potential for our solution. The first phase was part of a nationwide survey on the working conditions of French-speaking Belgian medical residents between 1 December 2020 and 30 June 2021. Based on the 2021 official registry in Belgium, the total number of Belgian French-speaking medical residents was 2937 [31]. This survey included questions about the opt-out clause (i.e. a voluntary provision allowing doctors to exceed the 48-hour work week set by the EWTD), duty activity (i.e. additional work ensuring continuity of care), remuneration and recovery (i.e. resting period legally defined), as well as current issues with employer-driven time-tracking solutions and protected time for training and research (a legal obligation in Belgium) [32] (File 1, available as Supplementary data at *Occupational Medicine* online). In the subsequent phase, we enrolled 12 alpha testers from diverse practice location centres, medical specialties, genders, years of training, and universities, ensuring a broad representation of healthcare contexts and needs within hospital settings.

Before the alpha test, we surveyed participants to measure their satisfaction with existing hospital-based occupational management systems to identify key challenges and expected benefits, establishing a baseline against which our tool's effectiveness could be evaluated. The survey consisted of closed and open questions exploring the time management routine of individuals, and organizational practices concerning working hours recording and payroll, the limitations faced, and their insights, for a more effective solution (File 2, available as Supplementary data at *Occupational Medicine* online).

Then, we implemented the prototype version of our solution to testers without training. This alpha version focused on core functionalities, that is, scheduling, time tracking and basic individual reporting. At that stage, it did not encompass advanced features such as intelligent and automated tracking. The alpha-testing phase spanned 16 May to 16 June 2022. Alpha testing refers to initial user

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testing of a prototype to evaluate core functionalities before wider use or more advanced features are developed [33]. Then, we conducted a post-test survey to measure the changes in time management practices and satisfaction levels to identify areas for further enhancement.

Agreement scores were reported on a Likert scale (i.e. 1–5 for strong disagreement to strong agreement). For consistency across all surveys and to ensure clarity in interpretation, we inverted the scoring for certain questions where higher numbers indicated less beneficial outcomes (e.g. questions 17 and 19 of the pre-test survey, and questions 3, 5, 7, 9 and 11 of the post-test survey), ensuring that a higher score consistently reflected more favourable outcomes throughout the results manuscript. We used Google Forms (Alphabet, Mountain View, CA) for electronic surveys. Pearson's chi-squared tests were employed to evaluate associations between categorical variables (e.g. medical specialty), and standardized residuals were analysed to identify specific categories. The Kruskal–Wallis rank sum test was used to assess relationships with ordinal variables (e.g. residency year). All analyses were conducted using two-tailed tests, with a significance threshold set at 0.05. Bonferroni correction was applied for multiple comparisons. The statistical analyses were performed using R version 4.2.3 [34]. The following R packages were used: readr (for reading CSVs reading) files [35], dplyr (for data manipulation) [35], stats (for the Chi-squared test and Kruskal–Wallis tests) [34], gmodels (for extracting standardized residuals extraction) [36] and ggplot2 for (generating mosaic plots generation) [37].

Given the nature of this study, which primarily involved developing and testing a technological solution for occupational stress management in healthcare workers, ethics approval was not required. The study did not involve clinical or personal data collection from patients or direct interventions with human subjects. It focused on the technical development and feasibility assessment of the application, relying on general feedback from healthcare professionals regarding its functionality and potential impact. Ethical considerations were addressed through informed consent and the voluntary nature of participation. No personal, identifiable or sensitive data were collected nor stored during any phase of the study without specific individual consent, and all data handling adhered to the European's GDPR—016/679 requirements. This approach aligns with ethical research practices as it does not involve sensitive personal data or direct human subject experimentation.

# Results

In our nationwide survey, we received responses from 257 French-speaking residents (Table 1, available as Supplementary data at *Occupational Medicine* online). The most represented medical specialties were paediatrics, with 56 participants (22%); internal medicine, with 49 (19%); and emergency medicine, with 34 (13%). A significant proportion of the respondents ($n$ = 180, 70%) were in their first 3 years of training. Of the respondents, 206 (80%) reported having signed an opt-out clause. On-site duty concerned 214 (83%) participants, on-call duty 58 (23%), and 6 (2%) were free of duty. Regarding recovery post-shifts, 139 respondents (54%) reported full recovery, 78 (30%)

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partial recovery and 34 (13%) no recovery (Table 2). Concerning duty compensation, 129 (50%) respondents reported being fully paid, 102 (40%) were partially paid and 17 (7%) were unpaid.

**Table 2.** Results of the nationwide survey

| **Duty type, *n*(%)** | |
|---|---|
| Total number of respondents | 253 (98) |
| On-site | 189 (75) |
| On-call | 33 (13) |
| Mixed | 25 (10) |
| None | 6 (2) |
| Mandatory post-duty recovery allocation, *n*(%) | |
| Total number of respondents | 251 (98) |
| Always | 139 (55) |
| Partially | 78 (31) |
| Never | 34 (14) |
| Duty compensation, *n*(%) | |
| Total number of respondents | 248 (97) |
| Fully | 129 (52) |
| Partially | 102 (41) |
| None | 17 (7) |
| Satisfaction of existing, in-house, working time account, mean (IQR) | 2.0 (2) |
| Extra-hours remuneration-related issues, *n*(%) | |
| Lack of payroll transparency hindering ability to evaluate remuneration adequacy | 107 (42) |
| Extra hours never paid | 86 (34) |
| Discordance in extra-hours count and payment | 57 (22) |
| Fully accounted and accordingly paid | 21 (8) |
| Protected academic time, *n*(%) | |
| Total number of respondents | 244 (95) |
| None | 189 (78) |
| For training | 52 (21) |
| For research | 16 (7) |

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| | |
|---|---|
| Interest in an independent, worker-centred solution, mean (IQR) | 4.55 (1.0) |

Among the respondents, 21 (8%) reported that their extra hours were always accounted for and paid, 57 (22%) experienced discordance in extra-hours count and payment, 107 (42%) reported a lack of payroll transparency hindering their ability to respond and 86 (34%) were unpaid for their extra hours. When rating the current hospital system for accounting for extra hours, 175 (68%) respondents scored 1 or 2, indicating the highest levels of dissatisfaction. In terms of protected time, 189 (74%) respondents reported having none, with 52 (20%) having protected time for training purposes and 16 (6%) for research.

Significant associations were found between specialty, both opt-out choices ($X^2$ = 16.685, df = 3, $P$ < 0.001) and duty recovery ($X^2$ = 63.223, df = 6, $P$ < 0.001). Standardized residuals indicated more opt-outs in surgery and fewer in critical specialties (i.e. anaesthesiology and emergency medicine). More full-duty recovery in the critical specialties and a higher absence of duty recovery in surgery, than would be expected under independence.

A significant relationship was found between duty recovery and duty pay ($X^2$ = 23.075, df = 4, $P$ < 0.001), where full-duty recovery was associated with full-duty pay. A significant relationship was also found between extra-hours pay and both duty recovery ($X^2$ = 22.011, df = 8, $P$ < 0.01) and duty pay ($X^2$ = 24.024, df = 8, $P$ < 0.01), where lack of transparency concerning extra-hours pay was associated with full-duty recovery or pay. A strongly significant relationship was observed between extra-hours pay and protected time ($X^2$ = 41.066, df = 8, $P$ < 0.001), as lack of transparency concerning extra-hours pay or unpaid extra hours was strongly associated with the absence of protected time. All significant relationships remained significant after applying the Bonferroni correction, with $P$-values below the adjusted threshold of 0.00625. No statistically significant relationship was found between duty recovery and protected time ($X^2$ = 6.9185, df = 4, $P$ = 0.14). Similarly, no statistically significant relationship was found between duty pay and protected time ($X^2$ = 4.2952, df = 4, $P$ = 0.37).

Finally, 235 (91%) respondents expressed a high interest (scored above 4) in an open, decentralized, worker-centred time-tracking solution. Interest levels did not significantly differ across specialties (Kruskal–Wallis $X^2$ = 4.1184, df = 3, $P$ = 0.25), gender groups (Kruskal–Wallis $X^2$ = 0.05549, df = 2, $P$ = 0.97), or training years (Kruskal–Wallis $X^2$ = 7.0455, df = 5, $P$ = 0.22).

Alpha testing was conducted with a representative group of 12 users (Table 3, available as Supplementary data at *Occupational Medicine* online). Of the 12 testers, 9 reported the independence and accuracy of the reporting, 7 the payroll verification, and 4 the employer counterbalance as the most expected benefits. Seven participants identified administrative overload from added time-tracking tasks, and five flagged initiative multiplicity due to divergent objectives from various time-tracking solutions, both as primary concerns.

After alpha testing, a mean score of 4.7 (IQR 1.0) was attributed to the independence and accuracy of the reporting, 4.1 (IQR 1.0) for payroll verification, and 4.2 (IQR 1.0) for employer counterbalance. Most participants expressed satisfaction (scores of 3 or above) with the prototype, and all indicated they would continue to use this solution following the testing phase. Regarding concerns, the administrative overload management achieved satisfaction at 3.7 (1.0), while initiative multiplicity

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and the anticipated benefit of improved time management did not reach satisfaction, scoring 2.7 (1.0) and 2.4 (1.0), respectively (Table 3).

**Table 3.** Alpha-testing pre- and post-survey results

| | **Pre-alpha testing, *N*** | **Post-alpha testing satisfaction, mean (IQR)** |
|---|---|---|
| Benefits | | |
| Independence and accuracy of the report | 9 | 4.7 (1.0) |
| Employer counterbalance | 4 | 4.2 (1.0) |
| Better time management | 3 | 2.4 (1.0) |
| Payroll verification | 7 | 4.1 (1.0) |
| Identification of abuses[a] | 1 | NA |
| Awareness of actual hours worked[a] | NA | 4.4 (1.0) |
| Downsides | | |
| Administrative overload | 7 | 3.7 (1.0) |
| Initiative multiplicity | 5 | 2.7 (1.0) |
| Overall user experience satisfaction | | 3.6 (0.5) |
| Usefulness of a time-tracking solution | | 4.1 (1.3) |

[a]Items were mentioned in the free-text zone but not in the pre-specified questions.

# Discussion

Our nationwide survey unveils a polarized situation, evidenced by correlations between full-duty recovery and pay, as well as between extra-hour compensation and duty recovery. Similarly, variations among specialties, such as the higher tendency among surgical residents to use the opt-out clause, indicate that improper practices may be influenced by institutional norms and medical culture. The opacity in worktime documentation, affecting 42% of residents, may exacerbate the under-recognition of such issues, a sentiment supported by 68% dissatisfaction with extra hours accounting in our survey.

Recently, a Belgian Federal Public Service Health quality assessment involving 1494 residents and 736 residency supervisors elucidated congruent patterns with our survey [38]. It indicated that 87% of respondents had accepted the opt-out clause, with 89% feeling pressured to use it, and 28% working beyond the 60-hour weekly legal limit [32,38,39]. Concerning resting time, 44% of our survey's respondents reported partly or not recovering shifts. These data imply a widespread violation of EWTD regulations, risking worker safety and patient care [22]. Compensation issues were

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also prevalent, as 46% of respondents in our survey reported being partly or not paid for their duty, contrasting with a mere 8% reporting that extra hours were always accounted for and paid. Such discrepancies constitute unpaid labour and highlight worker exploitation. Regarding protected time for training and research, 74% of residents indicated having none in our survey. Similarly, data from the federal survey suggests that only 14% had periods aligning with the definition of protected time [32]. Interestingly, the federal survey revealed that only 2% of residency supervisors recognized the lack of protected time, while 31% claimed that their residents were afforded this time [38]. This divide between residents and supervisors reveals a critical perception gap.

Together, these findings weave a nuanced picture of a multifaceted issue beyond mere legal compliance, implicating socio-cultural pressures, organizational failures and technological shortcomings in the intricate fabric of healthcare systems. In line with this, 91% of survey respondents expressed a strong interest in transitioning to an open, decentralized, worker-centred time-tracking solution.

In response, our proposed solution departs from conventional top-down occupational management practices that often concentrate on administrative compliance, short-sighted productivity metrics or cost-cutting measures despite real-world complexity and long-term sustainability. Our solution aims to harness rich data with resilience, versatility and granularity. Automation is central to minimizing human error, reducing administrative overhead and mitigating socio-cultural pressures—alpha testing yielded a 4.7 satisfaction score for reporting accuracy and independence, 3.7 for reduced administrative burden and 4.1 for payroll verification. Furthermore, it aggregates data into multi-level reports, informing stakeholders at various organizational levels and roles. Its user-centred design distinguishes it from conventional solutions. Therefore, this system is designed for a bottom-up integration of diverse stakeholder perspectives while maintaining worker agency. Its interface is devised to streamline onboarding and elevate user experience, targeting well-being, productivity and job satisfaction for healthcare workers. As a prototype, it garnered a mean user satisfaction score of 3.6, with unanimous intent for continued use among testers. Built on open-source and decentralized technologies, our solution promotes crowdsourcing and community-driven governance. The DAO model accentuates collective responsibility, aiming for societal impact. This open-access platform aspires to be an agent of cultural and political change, guiding policy-making and fostering competitive balance between healthcare employers. This is underscored by a 4.2 satisfaction score regarding employer counterbalance during alpha testing.

The incipient nature of this research complicates benchmarking. The study's focus on a specific locale with a selected cohort limits its generalizability and introduces selection bias, particularly as participants with a greater inclination toward technology may have been more likely to engage. The alpha-testing phase involved a small, non-representative sample, limiting the statistical power and generalizability of the findings, which should be interpreted as exploratory rather than conclusive. The prototype had limited functionalities. Concurrently, the landscape of time-tracking solutions for health workers is complex and fragmented, characterized by multiple, often non-interoperable, initiatives that are either employer-driven or mandated by governmental or union bodies. Such

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limitations may contribute to the hitherto unmitigated administrative burden and ineffective time management, as evidenced by dissatisfaction scores of 2.7 and 2.4.

There is a pressing need for innovation in workforce oversight in health care. We introduce a worker-centred solution for healthcare occupational management, integrating open-source machine intelligence and blockchain technology within a robust, adaptable framework. A strategic approach will be essential to navigating the prevailing medical culture, healthcare intricacies and diverging stakeholder interests while addressing technical and adoption hurdles. By equipping health workers with the tools to manage their time and amplify their contributions, we could empower them with greater agency, thereby safeguarding their well-being, elevating patient care and promoting systemic sustainability.

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## Competing interests

All authors have completed the Unified Competing Interest form (available on request from the corresponding author) and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years, but do declare relationships or activities that could appear to have influenced the submitted work: S.B. and A.N. are both funding members of an NGO advocating for Junior Doctors' rights and interests. They have been actively involved in the development and publishing of the described application.

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