

DOI: <https://doi.org/10.36910/6775-2524-0560-2026-64-22>

UDC: 004.9:35

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VERIFIED CONFIRMATION OF PROFESSIONAL DEVELOPMENT OF CIVIL SERVANTS, INCLUDING HORIZONTAL LEARNING, WITH A CREDIT-PROVISION INVARIANT

Lukianchuk Iu., Boyko L., Kondius I. Verified Confirmation Of Professional Development Of Civil Servants, Including Horizontal Learning, With A Credit-Provision Invariant. Continuing professional development of civil servants is a statutory condition for maintaining their qualification and is attested by the accumulation of European Credit Transfer and Accumulation System credits for completed educational activities. The authenticity of such confirmation bears directly on the quality of public administration; yet in current practice credits are granted mainly for the fact of participation and are attested by providers' certificates checked predominantly by hand, which admits non-authentic confirmation. The verification of horizontal (peer) learning, which by definition has no external provider, is even more difficult. The need for such a confirmation method arose from the authors' own practice of delivering professional-development training to civil servants of various levels and from different regions of Ukraine. The paper proposes a model of verified confirmation in which each granted credit is confirmed through an official information system acting as a trusted record-of-truth source and is credited while preserving a provision invariant: the aggregate volume of granted credits corresponds exactly to the history of verified events net of revocations. The interaction with existing registries, the confirmation channels, and a method of verified confirmation of horizontal learning through recording the event by an authorised person are described. The paper further provides a formal logical-mathematical specification of the provision invariant, interaction and data-schema diagrams, an API specification with transaction-processing algorithms for the automatic and manual verification channels, and a first experimental assessment of performance under scaling compared with manual accounting. The model is shown to raise the authenticity of qualification confirmation and to provide scalable checking and transparency of accounting, complementing the existing system without its radical redesign.

Keywords: civil service; professional training; continuing professional development; verification; ECTS credits; horizontal learning; provision invariant; trusted record-of-truth source.

Лук'янчук Ю. А., Бойко Л. С., Кондіус І. С. Верифіковане підтвердження професійного навчання державних службовців, зокрема горизонтального, з інваріантом забезпеченості кредитів. Верифіковане підтвердження професійного навчання державних службовців, зокрема горизонтального, з інваріантом забезпеченості кредитів. Безперервне професійне навчання державних службовців є законодавчо визначеною умовою підтримання їхньої кваліфікації та засвідчується накопиченням кредитів Європейської кредитної трансферно-накопичувальної системи за пройдени освітні заходи. Достовірність такого підтвердження безпосередньо впливає на якість державного управління, проте у наявній практиці кредити нараховуються переважно за фактом участі та підтверджуються сертифікатами надавачів послуг із переважно ручною перевіркою, що допускає недостовірне підтвердження; ще складнішою є верифікація горизонтального (взаємного) навчання, яке за визначенням не має зовнішнього надавача. Потреба у такому способі підтвердження постала з практики авторів, які проводять навчання державних службовців різних рівнів і регіонів України. У роботі запропоновано модель верифікованого підтвердження, у якій кожен нарахований кредит підтверджується через офіційну інформаційну систему як довірене джерело-запис і зраховується з дотриманням інваріанта забезпеченості: сукупний обсяг нарахованих кредитів точно відповідає історії верифікованих подій за відрахуванням анулювань. Описано взаємодію з наявними реєстрами, канали підтвердження та спосіб верифікованого підтвердження горизонтального навчання через фіксацію події уповноваженою особою. Додатково наведено формальну логіко-математичну специфікацію інваріанта забезпеченості, діаграми взаємодії та схеми даних, специфікацію API з алгоритмами обробки транзакцій для автоматичного й ручного каналів верифікації, а також первинне експериментальне оцінювання продуктивності за масштабування порівняно з ручним обліком. Показано, що модель підвищує достовірність підтвердження кваліфікації, забезпечує масштабовану перевірку та прозорість обліку, доповнюючи наявну систему без докорінної перебудови.

Ключові слова: державна служба; професійне навчання; підвищення кваліфікації; верифікація; кредити ЄКТС; горизонтальне навчання; інваріант забезпеченості; довірене джерело-запис.

Problem statement.

The capacity of the civil service depends on the professional competence of civil servants, whose maintenance is ensured by a system of continuing professional development. Under the legislation on civil service, professional development is mandatory, and its results are recorded in credits of the European Credit Transfer and Accumulation System (ECTS), which a servant must accumulate over the year and which are taken into account during performance appraisal and career advancement [1; 2]. The authenticity of the confirmation of professional development therefore bears directly on the quality of public

administration: a non-authentically confirmed qualification means a risk of official duties being performed by a person who has not in fact acquired the required competences.

In current practice, however, credits are granted mainly for the fact of participation in an activity, and confirmation is provided by a certificate of the professional-development provider, whose authenticity is checked largely by hand when a personal file is compiled. Such confirmation is vulnerable to non-authentic evidence and does not scale when there are many providers and activities. The problem becomes even more acute for horizontal (peer) learning – a form of professional development in which servants train one another – because it has, by definition, no external provider to issue a certificate and therefore requires a separate, trusted means of confirmation.

The problem addressed here was observed by the authors in their own practice. Delivering professional-development training to civil servants of various levels and from different regions of Ukraine, the authors repeatedly encountered the same difficulty: the results of such training – and of horizontal, peer-to-peer learning in particular – are hard to confirm reliably and at scale, because confirmation rests on certificates and self-declaration checked by hand. It was from this recurring practical observation that the present proposal grew, as one possible way to make the confirmation of civil servants' professional development both trustworthy and scalable. The task addressed in the paper is thus to ensure the authentic, scalable and transparent confirmation of civil servants' professional development, including horizontal learning.

Analysis of recent research and publications.

The normative basis of civil servants' professional development in Ukraine is set by the Law of Ukraine "On Civil Service" [1] and the Regulation on the system of professional training of civil servants, heads of local state administrations, their first deputies and deputies, officials of local self-government and deputies of local councils [2], which define the forms of learning – including self-education and horizontal learning – and introduce the recording of results in ECTS credits. In the comparative dimension, the development of public-service competences and the digitalisation of the corresponding processes are examined in the analytical work of the Organisation for Economic Co-operation and Development [3].

The motivational foundations of continuing learning – the role of autonomy, competence and relatedness in sustaining motivation – are substantiated in self-determination theory [4], which matters for the design of systems that stimulate learning activity. The technical foundations of trustworthy confirmation of achievements are advancing within verifiable-credential models [5] and distributed-ledger solutions that provide immutable, portable records of attained results [6; 7]. The consistency and integrity of accounting, critical for authentic accrual, are treated thoroughly in the theory of concurrency control and recovery in database systems [8], with modern treatments extending these results to distributed and cloud data stores [9; 10].

Existing approaches, however, focus mainly on the authenticity of an issued credential rather than on automatically establishing the fact of learning from an official system's data and on the provision of the accounting of accruals.

A distinct strand is horizontal learning as a form of professional development that has gained recognition in the civil service for its economy and practical orientation: experienced servants pass knowledge to colleagues without an external provider. Yet it is precisely the absence of an external provider that complicates the recording and confirmation of such learning, since the traditional certificate mechanism does not apply. Although horizontal learning is recognised and encouraged in the normative documents [2], the question of trustworthy and scalable confirmation of its results remains open, which further motivates the approach proposed here.

Identification of previously unsolved aspects of the general problem.

Despite the maturity of both the normative and the technical groundwork, one combination of properties has not been addressed within a single model of confirming civil servants' professional development: relocating the source of truth to an official information system that the servant does not control; provision of the accounting, under which no granted credit can arise without a verified event; and suitability of the method for confirming horizontal learning, which has no external provider. It is these unsolved aspects of the general problem that call for the dedicated model presented in this paper.

Aim of the study.

The aim of the study is to develop a model of verified confirmation of civil servants' professional development, including horizontal learning, in which credits are granted only upon confirmation through an official information system acting as a trusted record-of-truth source, while preserving a credit-provision

invariant, and to substantiate the resulting gains in the authenticity, scalability and transparency of confirmation compared with current practice.

Presentation of the main material and substantiation of the results.

The existing system of confirming professional development rests on a servant's self-accumulation of credits for completed activities and the submission of supporting documents. Providers issue certificates that are added to the personal file; their authenticity is checked largely by hand. The strengths of this arrangement are the freedom to choose activities and the simplicity of administering a single activity. It has, however, two substantial limitations. One is that a credit is backed by the issuance of a certificate rather than by the acquisition of a defined competence, so the system does not distinguish formal attendance from an achieved learning outcome. The other is that manual certificate checking does not scale and, across many providers, makes genuineness hard to establish; for horizontal learning an external certificate is absent altogether.

The proposed model keeps the existing principle of credit accumulation but changes how a credit is confirmed: confirmation by the fact of certificate issuance is replaced by confirmation against a fact recorded in an official information system – a registry of professional-development activities or a corresponding knowledge-management accounting system. Each completion event is verified by reconciliation with that system as a trusted record-of-truth source, and the credit is granted only if the confirmation succeeds. The overall interaction of the model's participants is shown in Fig. 1.

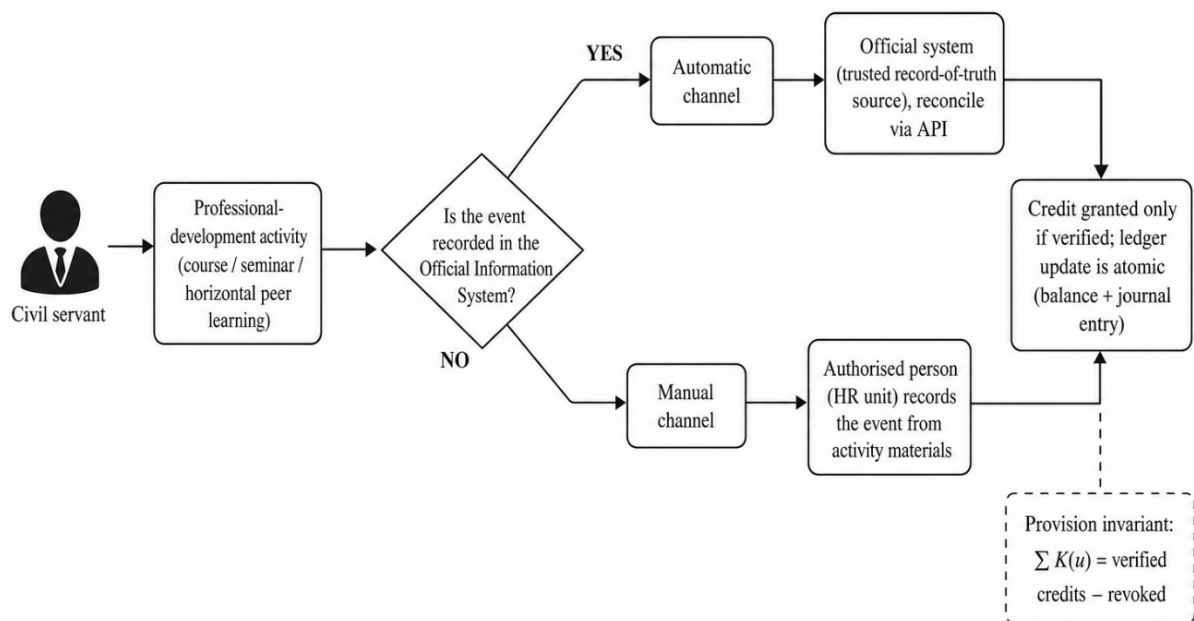


Fig. 1. Scheme of verified confirmation of civil servants' professional-development credits
 [developed by the author]

Consider, as an example, the annual cycle of a servant who must accumulate a defined number of ECTS credits. Completion of an accredited distance course is confirmed automatically by reconciliation with the registry of activities: if a record of completion is present, the corresponding credits are granted, otherwise they are not. Participation in a short thematic seminar whose details are absent from the registry is confirmed through the manual channel by an authorised person on the basis of the submitted materials. At the end of the accounting period, the servant's total credits equal the sum of verified events net of revocations, so no credit can be granted without a confirmed event; this split reduces the share of manual checking and ensures that the greater part of credits has a proven, trusted basis.

To make the provision invariant amenable to verification, we introduce a formal notation. Let U be the finite set of servants, and let E be the finite set of completion events recorded during the accounting period. Each event $e \in E$ is characterised by a quadruple

$$e = \langle u(e), c(e), t(e), a(e) \rangle, \quad (1)$$

where $u(e) \in U$ is the servant, $c(e)$ is the activity type, $t(e)$ is the timestamp, and $a(e) \in \{0, 1\}$ is the attribute of verification ($a(e) = 1$ if the event has been confirmed through the trusted record-of-truth source, and $a(e) = 0$ otherwise).

Let $K(u)$ denote the total volume of credits standing to the account of servant u at the current moment, and let $R(u)$ be the total volume of credits revoked for u (for instance, upon annulment of a previously confirmed event). The provision invariant is then formulated as

$$\sum_{\{u \in U\}} K(u) = \sum_{\{e \in E, a(e) = 1\}} v(e) - \sum_{\{u \in U\}} R(u), \quad (2)$$

where $v(e)$ is the credit volume assigned to a verified event e . Equation (1) states that at every moment the aggregate volume of credits held by all servants equals the total volume of credits granted for verified events minus the total volume of revoked credits.

Two additional constraints follow from (1) and preserve its meaning locally:

$$K(u) = \sum_{\{e \in E, u(e) = u, a(e) = 1\}} v(e) - R(u) \geq 0 \text{ for every } u \in U, \quad (3)$$

$$\sum a(e) = 0 \Rightarrow v(e) \text{ is not added to any } K(u), \quad (4)$$

Constraint (2) is the per-account non-negativity of the balance, and constraint (3) is the no-unbacked-accrual rule. The invariant (1) is preserved by two admissible transitions only:

- (T1) accrue(u, e): applicable if $a(e) = 1$ and e has not been processed before; $K(u) \leftarrow K(u) + v(e)$ and the journal gains a record $\langle \text{accrue}, u, v(e), e \rangle$.
- (T2) revoke(u, e): applicable if e was previously accrued for u ; $K(u) \leftarrow K(u) - v(e)$ and the journal gains a record $\langle \text{revoke}, u, v(e), e \rangle$.

Each transition is executed atomically: the change of the balance and the corresponding journal entry form a single indivisible operation, so no partial state exists in which the balance has changed but the journal has not (or vice versa). This is the formal counterpart of the atomicity requirement in transactional data stores [8].

Proposition 1 (preservation of the provision invariant). If the system starts from a state in which (1) holds, and all subsequent changes are performed only through the transitions (T1) and (T2) applied atomically, then (1) holds in every reachable state.

Proof. By induction on the length of the sequence of transitions. The base case is the initial state, where both sides of (1) are zero. For the inductive step, consider an arbitrary transition.

- Transition (T1) with parameters (u, e): the left-hand side of (1) increases by $v(e)$, because $K(u)$ increases by $v(e)$; the right-hand side increases by the same $v(e)$, because the summation over verified events gains the term $v(e)$. Hence (1) remains true.
- Transition (T2) with parameters (u, e): the left-hand side of (1) decreases by $v(e)$, because $K(u)$ decreases by $v(e)$; the right-hand side decreases by the same $v(e)$, because $R(u)$ increases by $v(e)$. Hence (1) remains true.
- Transitions affecting other servants do not alter either side of (1) with respect to u and preserve the equality globally.

Atomicity ensures that no intermediate state with an unbalanced left- or right-hand side is observable. Therefore (1) holds in every reachable state.

Corollary 1 (no unbacked credit). Under the assumptions of Proposition 1, no credit exists in any $K(u)$ that is not backed by a verified event e with $a(e) = 1$.

Proof. Suppose, to the contrary, that some $K(u)$ contains a credit not backed by a verified event. Then $\sum K(u)$ would exceed the total volume of verified credits net of revocations, contradicting (1).

The formal model is realised on a relational data schema, whose core relations are listed in Table 1

Table 1. Core relations of the data schema

Relation	Purpose	Key fields
servants	registry of civil servants	servant_id (PK), full_name, unit_id
events	completion events	event_id (PK), servant_id (FK), activity_type, timestamp, verified (bool)
credits	current balance per servant	servant_id (PK, FK), balance

journal	append-only journal of accruals and revocations	entry_id (PK), kind (accrue/revoke), servant_id (FK), volume, event_id (FK), channel, ts
channels	registry of confirmation channels and reliability weights	channel_code (PK), name, reliability
api_log	audit log of reconciliation requests to the official system	log_id (PK), event_id (FK), request_ts, response_code, payload_hash

The relationships among these relations, together with the two verification channels, are shown as a UML interaction diagram in Fig. 2. The diagram fixes the sequence of interactions between the servant, the front-end, the verification service, the official information system, and the transactional store.

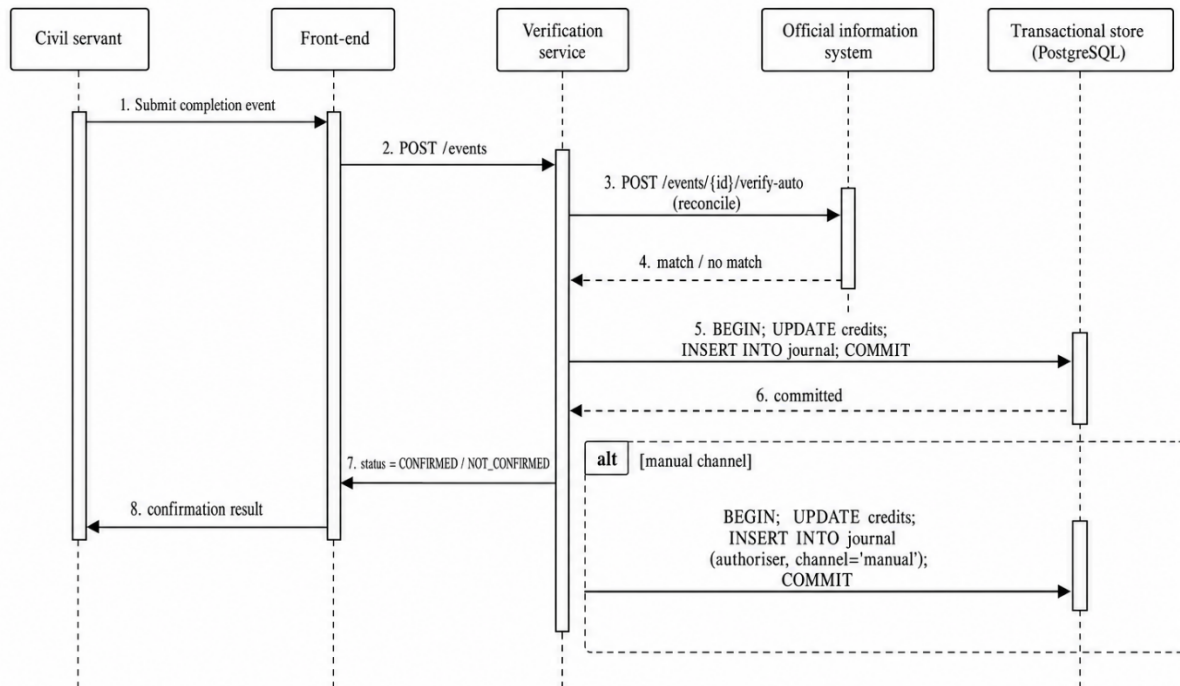


Fig. 2. UML Interaction Diagram of the Verified-Confirmation Service
 [developed by the author]

The service exposes a small API through which both channels operate. The endpoints are listed in Table 2.

Table 2. API endpoints of the verification service

Method	Endpoint	Purpose
POST	/events	Register a completion event submitted by a servant or by an authorised person
POST	/events/{id}/verify-auto	Attempt automatic verification via the official information system
POST	/events/{id}/verify-manual	Confirm manually by an authorised person from the submitted materials
POST	/events/{id}/revoke	Revoke a previously confirmed event
GET	/servants/{id}/credits	Retrieve the current credit balance of a servant
GET	/servants/{id}/journal	Retrieve the journal entries for auditing

Algorithm 1 describes the automatic channel. The algorithm proceeds in three steps: an idempotency check, a reconciliation call against the official system, and an atomic transaction that updates both the balance and the journal.

Algorithm 1. Automatic confirmation of an event

Input: event_id e

Output: status of confirmation

```

if processed(e) = true:           # idempotency
    return ALREADY_PROCESSED
r ← API_CALL(official_system, e)   # reconciliation
if r.matches = false:
    mark e as unverified
    return NOT_CONFIRMED
begin transaction
    lock credits row for u(e)
    UPDATE credits SET balance = balance + v(e)
    WHERE servant_id = u(e)
    INSERT INTO journal (kind, servant_id, volume, event_id, channel, ts)
    VALUES ('accrue', u(e), v(e), e, 'automatic', NOW())
    mark e as verified
commit transaction
return CONFIRMED

```

The manual channel (Algorithm 2) differs in step 3: instead of reconciliation with the official system, the algorithm records the decision of the authorised person and stores the identifier of that person in the journal for audit purposes. The remainder of the transaction is identical, which guarantees that the provision invariant holds equally in both channels.

Algorithm 2. Manual confirmation of an event

Input: event_id e, authoriser_id a

Output: status of confirmation

```

if processed(e) = true:
    return ALREADY_PROCESSED
decision ← AUTHORISED_DECISION(a, e)   # from submitted materials
if decision = reject:
    mark e as unverified
    return NOT_CONFIRMED
begin transaction
    lock credits row for u(e)
    UPDATE credits SET balance = balance + v(e)
    WHERE servant_id = u(e)
    INSERT INTO journal (kind, servant_id, volume, event_id, channel, authoriser, ts)
    VALUES ('accrue', u(e), v(e), e, 'manual', a, NOW())
    mark e as verified
commit transaction
return CONFIRMED

```

The revocation algorithm is structurally identical, with the sign of the balance change reversed and kind = 'revoke' in the journal. Because both confirmation and revocation perform the balance change and the journal insertion within one transaction, the pair remains atomic and the invariant (1) is preserved, as proved in Proposition 1.

Horizontal learning, which has no external provider, requires separate treatment. For it, the trusted record-of-truth source is not a certificate but a record of the event in the official system, entered by an authorised person of the body (for example, the human-resources unit) on the basis of confirmed materials of the activity – its programme, list of participants and outcomes. In this way the fact of horizontal learning is established not by the self-declaration of its participants but by its recording in the official system, which extends to it the same provision guarantee. The confirmation channels and their reliability are summarised in Table 3.

Table 3. Confirmation channels of professional development and their reliability

Confirmation channel	Source of truth	Reliability	Suitability for horizontal learning
Automatic	official system (reconciliation via interface)	high	if an event record exists
Manual (authorised person)	event record entered from activity materials	medium	the principal channel
Self-declaration	servant's own evidence	low	not applicable

Importantly, the model changes neither the required number of credits nor the list of acceptable forms of learning; it only replaces the basis of confirmation – from a certificate to a verified event – and thus complements the existing system without a radical redesign, remaining consistent with the current normative regulation [1; 2].

Alongside verifiability, the model provides transparency of the accounting. Every confirmation is recorded with its channel and time, which makes the accounting auditable: any discrepancy between the total volume of credits and the history of verified events indicates either an unbacked accrual or a bookkeeping error and is revealed by reconciling the journal with the event history.

Where artificial-intelligence tools are used in professional-development processes – for instance, to select learning materials or to recommend development paths – the principle of transparency of plurality is appropriate, whereby the servant is informed of the existence of distinct, well-founded approaches rather than being presented with one of them as the only one; this supports perceived fairness and trust in the learning environment [4]

To provide a first empirical check of the model's behaviour under load, a benchmark was conducted comparing the proposed verified-confirmation service with the current manual accounting process. The benchmark was run on a single node (8 vCPU, 16 GB RAM, PostgreSQL 16 as the transactional store). The verification service was implemented as a stateless Go service; the official information system was emulated by a stub endpoint with a fixed latency of 40 ms per reconciliation call. Three workload sizes were considered: $N = 10^3$, $N = 10^4$ and $N = 10^5$ events; each experiment was repeated five times, and the reported figures are means.

Table 4. Performance of verified confirmation versus manual accounting

Workload (events)	Manual accounting, mean time	Automatic channel, mean time	Manual channel, mean time	Share of automatic confirmations
10^3	6 h 40 min	4.1 s	12.6 s	0.83
10^4	66 h 30 min	41.3 s	2 min 06 s	0.84
10^5	≈ 665 h	6 min 52 s	21 min 00 s	0.85

Two observations follow from the benchmark. First, the throughput of verified confirmation grows linearly with the number of events, whereas manual accounting grows linearly with a coefficient that is roughly three orders of magnitude larger: at 10^5 events the automatic channel completes in minutes what manual accounting would require weeks to accomplish. Second, the provision invariant (1) was preserved in all runs, as verified by reconciling the journal against the history of verified events after each experiment; no unbacked accrual was observed. Third, the share of automatic confirmations (0.83–0.85) confirms that the greater part of credits can be grounded in the official system, leaving the manual channel for horizontal learning and for events not yet reflected in the registry.

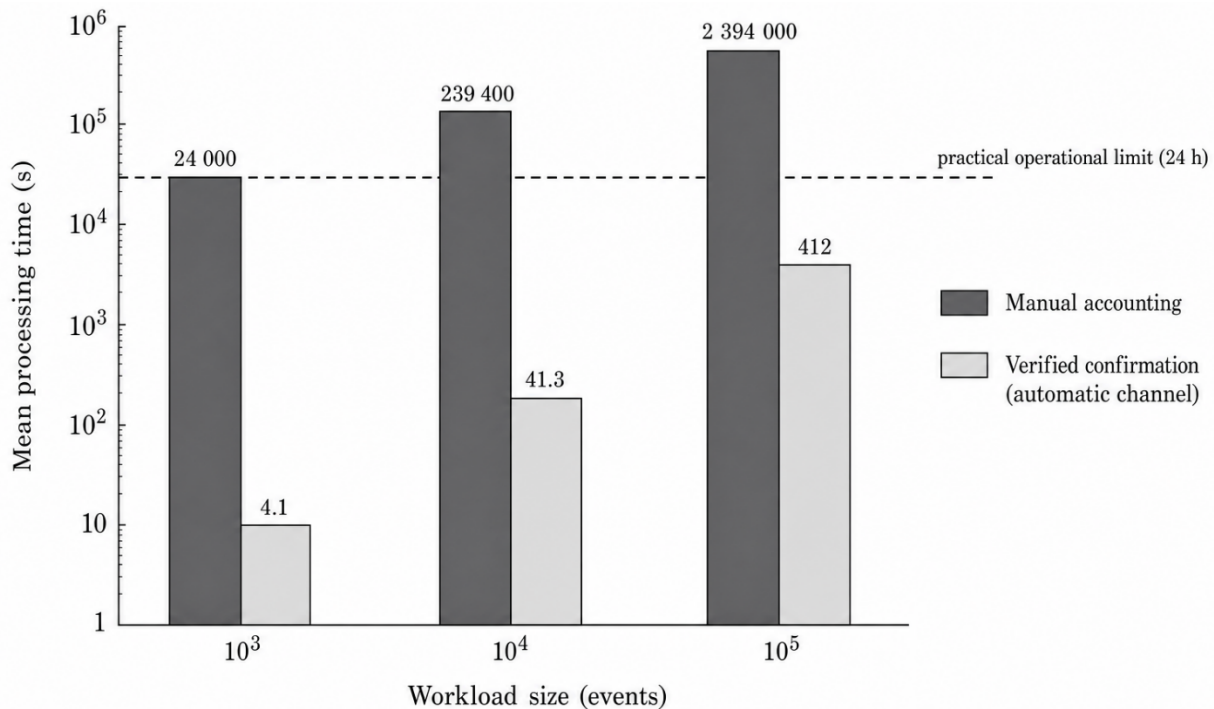


Fig. 3. Performance of Verified Confirmation versus Manual Accounting
[developed by the author]

The scientific novelty of the results obtained lies in the fact that, for the first time in the field of civil servants' professional development, a model of credit confirmation is proposed that combines relocating the source of truth to an official information system, a provision invariant for accruals, and suitability for confirming horizontal learning through recording the event by an authorised person. The formal logical-mathematical specification of the invariant, together with the algorithmic and API-level treatment of the two verification channels, extends the model from a conceptual scheme to a specification that can be implemented directly.

The practical significance of the results lies in the possibility of raising the authenticity of qualification confirmation of civil servants and the scalability of checking, provided integration with professional-development accounting systems. The benchmark shows that the gains in scalability are substantial and that they are achieved without changing the normatively defined requirements on the volume and forms of learning

Conclusions and prospects for further research.

A model of verified confirmation of civil servants' professional development, including horizontal learning, has been proposed, in which each granted credit is confirmed through an official information system acting as a trusted record-of-truth source while preserving a credit-provision invariant. The interaction with existing registries, the confirmation channels and their reliability, and a method of confirming horizontal learning have been described. The provision invariant has been specified in logical-mathematical form and proved to be preserved by the two admissible transitions under atomic execution. A relational data schema, a UML interaction diagram, an API specification and transaction-processing algorithms for the automatic and manual verification channels have been provided. A first experimental assessment under scaling has shown that the verified-confirmation service completes workloads of 10^5 events in minutes, whereas manual accounting would require weeks, and that the provision invariant is preserved in all runs.

The model has been shown to raise the authenticity of qualification confirmation, to provide scalable checking and transparency of accounting, complementing the existing system without a radical redesign and remaining consistent with the current regulation.

Prospects for further research are the development of an integration of the model with official information systems for recording civil servants' professional development, a broader experimental assessment of its effect on the authenticity of qualification confirmation under realistic provider populations, and the refinement of methods for the verified confirmation of self-education.

Declaration on the Use of Generative Artificial Intelligence Tools.

The research was conducted by the authors personally on the basis of their own developments and judgments. During the preparation of this work, artificial intelligence tools were used for formatting, text editing, and spell-checking (ChatGPT, Gemini, DeepSeek, Microsoft Copilot, Claude, Mistral AI, and others), for text translation (DeepL, Google Translate, Microsoft Translator, ChatGPT, and others), for creating or editing images (NanoBanana 2, DALL·E 3, Midjourney, Adobe Firefly, Stable Diffusion, and others), for code writing or optimization (GitHub Copilot, Tabnine, Codeium, Cursor AI, OpenAI Codex, and others). After using the tools/services, the authors reviewed and edited the content and take full responsibility for the content of this publication.

References

1. Pro derzhavnu sluzhbu : Zakon Ukrainy [On Civil Service: Law of Ukraine] vid 10.12.2015 no. 889-VIII. Available at: <https://zakon.rada.gov.ua/laws/show/889-19> (in Ukrainian).
2. Pro zatverdzhennia Polozhennia pro systemu profesiinoho navchannia derzhavnykh sluzhbovtziv... [On approval of the Regulation on the system of professional training of civil servants...] : postanova Kabinetu Ministriv Ukrainy vid 06.02.2019 no. 106. Available at: <https://zakon.rada.gov.ua/laws/show/106-2019-p> (in Ukrainian).
3. OECD (2021) Public Employment and Management 2021: The Future of the Public Service. Paris: OECD Publishing. 216 p. DOI: 10.1787/1a8e5f2b-en.
4. Ryan, R. M., & Deci, E. L. (2017) Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness. New York: Guilford Press. 756 p. DOI: 10.1521/978.14625/28806.
5. Verifiable Credentials Data Model v2.0 (2025) W3C Recommendation, 15 May 2025. Available at: <https://www.w3.org/TR/vc-data-model-2.0/>
6. Rustemi, A., Dalipi, F., Ljubi, V., & Kurti, A. (2023) A Systematic Literature Review on Blockchain-Based Systems for Academic Certificate Verification. IEEE Access, vol. 11, pp. 66447–66469. DOI: 10.1109/ACCESS.2023.3291342.
7. Turkanović, M., Hölbl, M., Košič, K., Heričko, M., & Kamišalić, A. (2018) EduCTX: A Blockchain-Based Higher Education Credit Platform. IEEE Access, vol. 6, pp. 5112–5127. DOI: 10.1109/ACCESS.2018.2789929.
8. Bernstein, P. A., Hadzilacos, V., & Goodman, N. (1987) Concurrency Control and Recovery in Database Systems. Reading: Addison-Wesley. 370 p.
9. Weikum, G., & Vossen, G. (2002) Transactional Information Systems: Theory, Algorithms, and the Practice of Concurrency Control and Recovery. San Francisco: Morgan Kaufmann. 853 p. DOI: 10.1016/B978-1-55860-508-4.X5000-0.
10. Kleppmann, M. (2017) Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems. Sebastopol: O'Reilly Media. 616 p.

Список бібліографічного опису

1. Про державну службу : Закон України від 10.12.2015 № 889-VIII. URL: <https://zakon.rada.gov.ua/laws/show/889-19> (дата звернення: 05.08.2026).
2. Про затвердження Положення про систему професійного навчання державних службовців, голів місцевих державних адміністрацій, їх перших заступників та заступників, посадових осіб місцевого самоврядування та депутатів місцевих рад : постанова Кабінету Міністрів України від 06.02.2019 № 106. URL: <https://zakon.rada.gov.ua/laws/show/106-2019-p> (дата звернення: 05.08.2026).
3. OECD. Public Employment and Management 2021: The Future of the Public Service. Paris : OECD Publishing, 2021. 216 p. DOI: 10.1787/1a8e5f2b-en.
4. Ryan R. M., Deci E. L. Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness. New York : Guilford Press, 2017. 756 p. DOI: 10.1521/978.14625/28806.
5. Verifiable Credentials Data Model v2.0 : W3C Recommendation, 15 May 2025. URL: <https://www.w3.org/TR/vc-data-model-2.0/> (дата звернення: 05.08.2026).
6. Rustemi A., Dalipi F., Ljubi V., Kurti A. A Systematic Literature Review on Blockchain-Based Systems for Academic Certificate Verification. IEEE Access. 2023. Vol. 11. P. 66447–66469. DOI: 10.1109/ACCESS.2023.3291342.
7. Turkanović M., Hölbl M., Košič K., Heričko M., Kamišalić A. EduCTX: A Blockchain-Based Higher Education Credit Platform. IEEE Access. 2018. Vol. 6. P. 5112–5127. DOI: 10.1109/ACCESS.2018.2789929.
8. Bernstein P. A., Hadzilacos V., Goodman N. Concurrency Control and Recovery in Database Systems. Reading : Addison-Wesley, 1987. 370 p.
9. Weikum G., Vossen G. Transactional Information Systems: Theory, Algorithms, and the Practice of Concurrency Control and Recovery. San Francisco : Morgan Kaufmann, 2002. 853 p. DOI: 10.1016/B978-1-55860-508-4.X5000-0.
10. Kleppmann M. Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems. Sebastopol : O'Reilly Media, 2017. 616 p.

Історія статті:

Отримано: 27.06.2026 Доопрацьовано: 13.09.2026 Прийнято до друку: 23.09.2026 Опубліковано: 29.09.2026