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A Digital Transformation Model for Developing and Managing Training Schedules at the Academic Affairs Office of a University

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ABSTRACT: Developing and managing training schedules is a core task of the academic affairs office, involving curricula, learners, lecturers, and facilities at the same time. Under the credit-based system, the volume of data and the number of constraints increase rapidly, so manual spreadsheet-based practices easily lead to scheduling conflicts, slow adjustments, and weak monitoring of implementation. This paper adopts a conceptual research approach combined with a structured literature review: documents were retrieved from Scopus, Google Scholar, and the National Database of Legal Documents using four keyword groups and screened against defined criteria, yielding 16 scientific works and 3 policy documents; their content was examined through directed content analysis and cross-checked using a claim–management function matrix. The result is a digital transformation model for training schedule management comprising six components: source data; data standardization and integration; schedule development; operation and monitoring; analysis and alerts; and decision support and improvement, linked by two feedback loops, within and between semesters. Most individual activities in the model are drawn from prior work; the paper's contribution lies in placing schedule development and implementation monitoring within a single data loop, together with seven monitoring indicators with defined formulas and data sources, and a three-phase implementation roadmap with explicit criteria for moving between phases. The model is conceptual and has not yet been validated with operational data from a specific university.

KEYWORDS: digital transformation, training schedule, timetabling, academic affairs office, university governance.

1. INTRODUCTION

Digital transformation has become a strategic direction for higher education. In Vietnam, education is one of the priority sectors of the National Digital Transformation Programme [1], and the Scheme on Strengthening the Application of Information Technology and Digital Transformation in Education and Training set the target that, by 2025, all learners and teachers would be managed through digital records with unified identifiers [2]. International studies show that digital transformation in universities is not merely the digitization of teaching materials but encompasses governance, business processes, data, and people [3], [4].

Among academic administration tasks, developing and managing training schedules is a core responsibility of the academic affairs office. In this paper, the training schedule is understood as the system of time-based plans for organizing training, including the academic-year plan, the plan for opening course sections, timetables, and examination schedules, together with the monitoring and adjustment of these plans during implementation. The regulation on undergraduate training requires institutions to develop and publish teaching plans and timetables before each semester [5]. Under the credit-based system, learners register for courses themselves, so the number of course sections, the combinations of learners, lecturers, and rooms, and the number of constraints to be satisfied increase rapidly. Manual practices based on spreadsheets and paper correspondence easily lead to scheduling conflicts, slow adjustments when changes occur, and weak monitoring of implementation.

The timetabling problem has been studied for decades, but mainly from an algorithmic perspective [6], [7]. Organizing data, processes, and implementation monitoring as an integrated governance whole, especially in resource-constrained institutions, has received less attention. This paper proposes a digital transformation model for developing and managing training schedules at the academic affairs office of a university, together with a set of monitoring indicators and an implementation roadmap. The scope is the academic affairs office of a credit-based university with limited resources. The paper does not analyse the current situation of a specific institution; the result is a conceptual model that serves as a framework for situational surveys and pilots in subsequent studies. The remainder of the paper reviews the literature, identifies the research gap, and describes the method (Sections 2.1–2.5); presents the model, the relationships among its components, the indicator set, the implementation roadmap, and the discussion (Sections 2.6–2.11); and presents conclusions and recommendations (Section 3).

2. RESEARCH CONTENT

2.1. Digital transformation in university governance

Vial [8] defines digital transformation as a process that aims to improve an organization by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies. Under this definition, technology is only an enabler;

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outcomes depend on changes in the organization's structure, processes, and capabilities. The systematic review by Benavides et al. [3] shows that digital transformation in universities takes place along several dimensions: teaching, infrastructure, curricula, governance, research, human resources, and business processes; most studies focus on teaching, while governance and processes remain under-researched.

Rodríguez-Abitia and Bribiesca-Correa [9] assessed the level of digital transformation in universities and concluded that the sector lags behind many others, mainly for organizational and cultural rather than technological reasons. Mohamed Hashim et al. [10] emphasize that digital transformation in higher education must be strategy-led and cannot be a collection of disconnected software projects. Alenezi [4] points to the need to redesign processes and operating models alongside technology investment. Regarding data, Daniel [11] argues that big data analytics opens up opportunities for decision support at both the strategic and operational levels of an institution, provided that data are integrated and quality-assured.

Three principles for the digital transformation of an academic administration task can be derived from these works: data must be standardized and shared; processes must be redesigned before being automated; and outcomes must be measurable through specific indicators.

2.2. Training schedules and the timetabling problem

Mathematically, timetabling is the problem of allocating teaching activities to time slots and rooms so that a set of constraints is satisfied. Schaerf [6] distinguishes three classes of the problem: school timetabling, university course timetabling, and examination timetabling. Constraints are divided into two types. Hard constraints are mandatory conditions; for example, a lecturer, a room, or a learner cannot be in two classes at the same time, and room capacity must not be smaller than class size. Soft constraints are desirable conditions, such as limiting learners' idle periods within a day or distributing a lecturer's teaching hours evenly across the week; the degree to which soft constraints are satisfied determines the quality of a timetable [12], [13].

Because the problem is computationally complex, optimal solutions cannot be found by exhaustive enumeration at realistic scales; research has therefore focused on approximate search methods. Babaei et al. [14] classify the approaches into operations research, heuristic and metaheuristic search, multi-criteria approaches, and artificial intelligence methods. Chen et al. [15] observe a trend towards hybrid methods and point out a considerable gap between benchmark problems in research and the real problems faced by institutions. Ceschia et al. [7] summarize problem formulations, benchmark datasets, and best-known results, noting that each institution has its own set of constraints, which makes general-purpose solutions difficult.

In addition to course timetabling, examination scheduling is a separate problem with different constraints: learners must not sit two examinations in the same session, the interval between a learner's examinations must be sufficiently long, and the number of rooms and invigilators must be adequate for each session. The two problems are closely related because they use the same course registration data and room pool, and the examination schedule determines when grades are finalized, academic standing is reviewed, and registration for the next semester opens.

In terms of time horizons, the training schedule consists of three nested levels. The academic-year level sets the main milestones: the start and end of semesters, registration periods, examination periods, internships, and graduation reviews. The semester level determines the list of course sections to be opened, the lecturers in charge, and the weekly timetable. The week and day level covers the delivery of each class session and any adjustments that arise. Deviations at the lower levels, if not recorded and handled promptly, accumulate at the higher levels and manifest as compressed teaching at the end of the semester, postponed examinations, and delayed grade release.

A common feature of this research stream is that input data are assumed to be complete and accurate, and the task is considered finished once a timetable has been generated. In management practice, the training schedule has a broader scope: it begins with the academic-year plan, continues through course opening, teaching assignment, and scheduling, and extends to monitoring teaching hours, handling absences and make-up classes, organizing examinations, and finalizing grades.

2.3. Practical applications of scheduling systems and the Vietnamese context

Several universities have reported experience in applying institution-wide scheduling systems. At Purdue University (United States), Rudová et al. [16] describe a timetabling system in actual use, in which the institution-wide problem is decomposed into a problem for large lecture rooms scheduled centrally by the university and problems scheduled by individual departments; the system allows schedulers to intervene interactively and handles changes arising after publication according to the principle of minimal perturbation of the existing timetable. At Masaryk University (Czech Republic), Müller and Rudová [17] applied curriculum-based timetabling with elective courses and multiple parallel course sections, using curriculum data to forecast demand before learners register.

These two cases offer three lessons. First, a large problem should be decomposed according to the management hierarchy between the university and its faculties. Second, schedulers retain the decisive role; the system supports constraint checking and proposes options rather than replacing people. Third, handling changes after publication is as important as initial scheduling.

In Vietnam, in addition to the targets on digital records for learners and teachers, the education digital transformation scheme also aims for all eligible administrative procedures to be provided online at a high level by 2025 [2]. Many universities have adopted academic management software with course registration and timetabling modules. However, according to the principles derived in Section 2.1, having software does not equal digital transformation: if data on curricula, lecturers, and rooms remain scattered across units and implementation monitoring still relies on class logbooks and paper reports, schedule management remains at the level of computerizing individual tasks.

2.4. Research gap

A comparison of the selected works shows that each research stream has addressed part of the training schedule problem while leaving different issues open (Table 1). The digital transformation stream has established the concept, the dimensions of transformation, and ways of assessing the level of digital transformation at the institutional level, but has not shown how to transform a specific task. The timetabling stream has sufficiently powerful constraint models and algorithms, yet its own reviews [7], [15] acknowledge the gap between benchmark and real problems, owing to the assumption that input data are accurate and that the task ends once a timetable is generated. Systems applied in practice [16], [17] have addressed problem decomposition and post-publication changes, but in large institutions with dedicated teams, and implementation data have not

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been used as inputs for the following semester. The process management and data analytics stream provides general methods [18], [19] that have not yet been tailored to training schedules.

Accordingly, the gap addressed by this paper consists of three open issues: (i) there is no model that treats schedule development and schedule implementation management as two halves of a single data loop, in which implementation data feed back to calibrate the data and constraints of the next semester; (ii) there is no set of training schedule monitoring indicators specified down to calculation formulas and data sources; and (iii) there is no phased implementation roadmap with criteria for moving between phases that suits resource-constrained universities.

Table 1. Summary of research streams: issues addressed and issues remaining open

Research stream	Issues addressed	Issues remaining open relative to the objectives of this paper
Digital transformation in higher education [3], [4], [8]–[10]	Concept of digital transformation; dimensions of institutional transformation; role of strategy, organization, and culture; assessment of the level of digital transformation	Discussed at the institutional level; does not show how to transform a specific task such as training schedule management or how to measure its outcomes
Course and examination timetabling [6], [7], [12]–[15]	Problem classification; modelling of hard and soft constraints; systematization of algorithms and benchmark datasets	Assumes complete and accurate input data; stops once the timetable is generated; does not consider implementation or data responsibility
Scheduling systems applied in practice [16], [17]	Decomposition by university–faculty hierarchy; interactive scheduling; minimal-perturbation handling of post-publication changes; demand forecasting from curricula	Tied to large institutions with dedicated teams; implementation data not used to calibrate the next semester; no roadmap for resource-constrained institutions
Process management and data analytics [11], [18], [19]	Process modelling and redesign methods; conditions for data integration; dashboard design by user group	General methods; not yet translated into indicators and alert thresholds for training schedules
Vietnamese policies and regulations [1], [2], [5]	Establish digital transformation targets; require teaching plans and timetables to be developed and published	State requirements and targets; do not prescribe a model for organizing data, processes, or implementation monitoring

Source: Compiled by the author from the works cited in the table.

2.5. Research methodology

The study is a conceptual study following a model-building approach [20], using a structured literature review [21] and directed content analysis [22]; it does not use survey data or operational data from a specific institution. The methodological works cited above serve as methodological grounds and are not part of the set of analysed documents. The procedure comprises three steps.

Step 1 – Literature search and screening. Scientific literature was retrieved from Scopus and supplemented with Google Scholar; policy documents were retrieved from the National Database of Legal Documents (vbpl.vn). Four groups of English keywords were searched in titles, abstracts, and keywords: (1) "digital transformation" AND ("higher education" OR universit*); (2) ("course timetabling" OR "examination timetabling" OR "educational timetabling") AND (survey OR review OR "real-life"); (3) "business process management" OR "process redesign"; and (4) (dashboard* OR analytics OR "big data") AND ("higher education" OR "decision support"). Policy documents were searched using the Vietnamese terms for "digital transformation", "education and training", and "undergraduate training regulation".

Documents were included if they met all three criteria: (a) they were peer-reviewed journal articles, scholarly monographs, or legal or policy documents currently in force; (b) they related directly to at least one function of training schedule management (data, schedule development, implementation and monitoring, decision-making and improvement); and (c) their bibliographic information was verifiable. Documents were excluded if they only proposed algorithmic improvements on benchmark datasets without addressing data, processes, or operations (this group is covered by the review articles), were non-peer-reviewed conference reports, or duplicated content. Review articles and works describing systems in actual operation were prioritized. Screening was carried out in two rounds (title and abstract; full text) and supplemented by backward searching of the reference lists of review articles. As a result, 16 scientific works published between 1999 and 2023 and 3 policy documents issued between 2020 and 2022 were included in the analysis; the 16 works fall into four groups: digital transformation in higher education (5 works), course and examination timetabling (6), scheduling systems applied in practice (2), and process management and data analytics (3).

Step 2 – Coding and content analysis. The unit of analysis is the claim, that is, a statement, proposal, or finding that can be linked to training schedule management. Each claim was coded along two dimensions. The first is the document group (the four groups above). The second is the management function that the claim supports, using six codes defined in advance from the training schedule cycle described in Section 2.2: data collection; data standardization; schedule development; implementation and adjustment; analysis and monitoring; and decision-making and improvement. Claims that did not match any code were recorded separately for consideration as additional codes. The coding results were organized into a claim–function matrix showing which documents support each function, where the documents agree or differ, and which functions receive little attention.

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Step 3 – Synthesis into a model. Each function in the matrix was converted into a component of the model if it met two conditions: it was supported by at least two documents or by current regulations; and it could be assigned to a specific actor (the academic affairs office, a faculty, or a data management unit). For each component, the author identified three parts: what is inherited from the literature; what is adapted to the context of the academic affairs office of a resource-constrained university; and what is added in matrix cells that were empty or weakly supported (Table 2). Relationships among the components were established according to the data flow, in which the output of one component is the input of the next (Figure 1). Indicators were defined at points in the data flow where plans can be compared with implementation, and the roadmap was built on the principle of redesigning processes before automating them [18].

2.6. The digital transformation model for training schedule management

The proposed model comprises six components linked by a data flow from source data to management decisions (Figure 1). The first three components serve schedule development; the last three serve implementation management.

Component 1 – Source data. This component comprises five groups of data: curricula, learners, lecturers, facilities, and the academic-year time frame.

Component 2 – Data standardization and integration. This component establishes shared catalogues with unified identifiers for courses, classes, lecturers, and rooms; assigns the units responsible for updating each data group; and connects management modules so that data are entered once and used in many places. It is the foundation layer, corresponding to the data integration requirement that Daniel [11] regards as a prerequisite for analytics.

Component 3 – Schedule development. This component performs a chain of tasks: planning the academic year; forecasting demand and opening course sections; assigning lecturers; scheduling timetables and examinations with automated constraint checking; and approving and publishing the schedule. The checking of hard constraints and the evaluation of soft constraints draw on the models of Burke and Petrovic [12] and Lewis [13].

Component 4 – Operation and monitoring. This component records the day-to-day implementation of the schedule: confirmation of teaching hours, reported absences and make-up class requests, room and lecturer changes, and the progress of examinations and grade entry. All changes are processed through electronic approval workflows and immediately reflected in the official schedule.

Component 5 – Analysis and alerts. This component compares the published schedule (Component 3) with implementation data (Component 4), aggregates them into indicators, displays them on visual dashboards, and issues alerts when course sections fall behind schedule, conflicts arise, or overloads occur.

Component 6 – Decision support and improvement. This component supports the leadership of the academic affairs office and the university in making in-semester adjustment decisions, while distilling data to improve schedule development for the following semester.

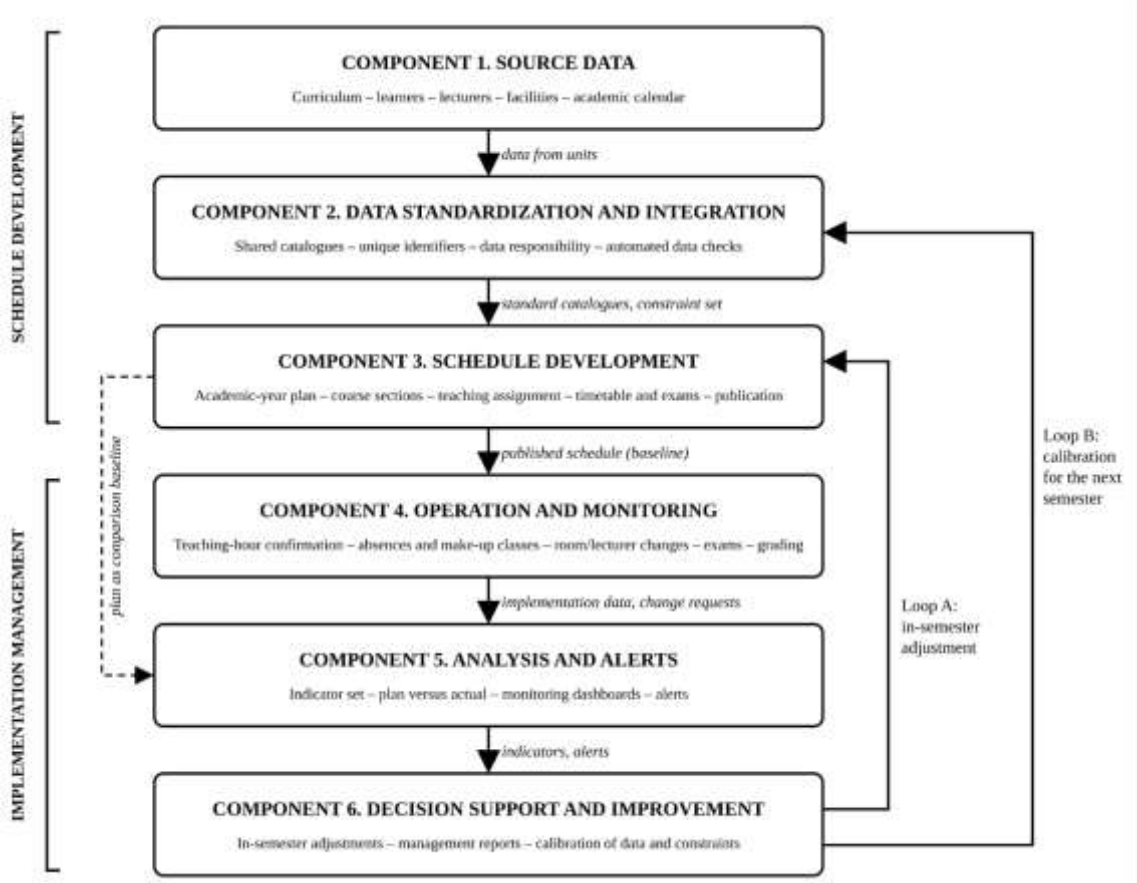

Figure 1. Digital transformation model for developing and managing training schedules
Source: Proposed by the author based on a synthesis of [3], [11], [12], [16], [18], and [19].

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Relationships among the components are defined by the data flow and expressed through three types of links in Figure 1. The first type consists of sequential links: data from units (Component 1) are used for scheduling only after being standardized and checked (Component 2); standard catalogues and the constraint set are the inputs of Component 3; and the approved and published schedule becomes the baseline for Component 4. The second type is the comparison link: Component 5 receives not only implementation data from Component 4 but also the published schedule from Component 3 as a reference point, because every schedule indicator is a comparison between plan and implementation. Component 3 must therefore retain the published version of the schedule and all approved revised versions; otherwise, Component 5 has no basis for calculating indicators.

The third type consists of two feedback loops originating from Component 6. Loop A operates within the semester: when alerts show that a course section is behind schedule or a conflict has arisen, the adjustment decision (scheduling a make-up class, changing the room, or changing the lecturer) is returned to Component 3 as a new schedule version and then monitored in Component 4. Loop B operates between semesters: accumulated implementation data, such as the actual registration rate for each course, the frequency of schedule changes by cause, and the utilization of each room, are used to calibrate catalogues, norms, and constraint weights in Component 2 for the following semester. Loop A ensures that the schedule is implemented as planned; Loop B ensures that the quality of schedule development improves from one semester to the next. Through these two loops, schedule management shifts from one-off planning to a data-driven management cycle.

Table 2 presents the results of comparing the six components of the model with the analysed literature, identifying what is inherited, adapted, and added. Most activities within each component have already been addressed in the fields of academic administration and information systems; the model's additions are concentrated in Components 2, 4, 5, and 6 and in the way the components are linked into two feedback loops, rather than in individual activities.

Table 2. Comparison of the six model components with prior studies

Component	Inherited elements and sources	Adaptations to the academic affairs office context	Additions of this paper
1. Source data	Input data and constraints of the timetabling problem [6]; curriculum data for demand forecasting [17]; requirements for teaching plans [5]	Grouped into five data groups, each linked to the unit currently managing it within the university	Mainly inherited; no significant additions
2. Data standardization and integration	Data integration as a precondition for analytics [11]; unified identifiers and digital records [2]	Specified as shared catalogues for courses, classes, lecturers, and rooms	Assignment of responsible units, data cut-off deadlines, and automated data checks before each scheduling round; receipt of calibration data from Loop B
3. Schedule development	Hard and soft constraint models [12], [13]; university–faculty decomposition and interactive scheduling [16]	Organized as a five-step process with defined inputs, outputs, responsible units, and deadlines [18]; constraint set issued as internal regulations	Retention of the published schedule and approved revised versions as the baseline for Component 5
4. Operation and monitoring	Minimal-perturbation handling of post-publication changes [16]	All changes initiated and approved in the system; automatic notification to stakeholders	Daily implementation data (teaching-hour confirmation, absences and make-up classes, grade entry) treated as the official data source for monitoring and for the next semester; changes recorded by cause
5. Analysis and alerts	Dashboards by user group [19]; data analytics for decision support [11]	Layered dashboards for university leadership, office and faculty leadership, and staff	Set of seven schedule indicators with calculation formulas, data sources, and reporting periods (Table 4)
6. Decision support and improvement	Digital transformation as data-driven organizational change [8]; continuous process improvement [18]	Distinction between in-semester and between-semester decisions	Two feedback loops (A and B); three-phase roadmap with criteria for moving between phases (Table 5)

Source: Compiled by the author from the content analysis.

2.7. Input data and the constraint set

The quality of a schedule depends first and foremost on the quality of its input data. The five data groups of Component 1 are managed by different units, so the responsible unit and the data cut-off deadline before each semester must be clearly specified (Table 3). Many post-publication timetable adjustments may stem not from the scheduling algorithm but from incorrect or late data: rooms under repair that have not been declared, lecturers on business trips, or class sizes that change after supplementary registration.

Therefore, before each scheduling round, the system should perform automated data checks: courses without a suitably qualified lecturer; rooms whose capacity is smaller than the expected class size; lecturers exceeding their workload norms; and courses opened in a semester that

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does not match the curriculum. The results are sent to the responsible units for resolution before the cut-off deadline, replacing manual reviews by the academic affairs office.

Table 3. Input data groups for training schedule development

Data group	Main content	Responsible unit	Role in scheduling
Curriculum	Courses, credits, theory and practice hours, prerequisites, allocation by semester	Academic faculties, academic affairs office	Determines the workload to be organized in each semester
Learners	Cohort, major, class, academic status, course registration results	Academic affairs office, student affairs office	Determines the number and size of course sections; learner no-overlap constraints
Lecturers	Expertise, standard teaching-hour norms, availability	Academic faculties, personnel office	Teaching assignment; no-overlap and workload-limit constraints
Facilities	Classrooms, workshops, laboratories; capacity, equipment, maintenance schedules	Facilities management office	Capacity and room-type constraints; balancing utilization
Time frame	Academic-year plan, teaching weeks, sessions, holidays, examination and internship periods	Academic affairs office	Defines the permissible time domain for timetables and examination schedules

Source: Compiled by the author based on [5], [6], and [17].

The constraint set should be issued by the academic affairs office as internal regulations before being entered into the system. Hard constraints include: no overlaps for lecturers, rooms, and learners; room capacity and type appropriate to the course section; and compliance with the academic-year time frame and course prerequisites. Soft constraints include: limiting learners' idle periods and the number of days they must attend campus; distributing lecturers' teaching hours evenly; limiting travel between campuses; and prioritizing workshops and laboratories for practical courses. Each soft constraint is assigned a weight reflecting the university's priorities, which serves as the basis for comparing alternatives.

2.8. The digital process for training schedule development

According to Dumas et al. [18], automation is effective only when processes have been modelled, analysed, and redesigned. Applying this principle, schedule development is organized into five steps, each with inputs, outputs, a responsible unit, and a deadline defined in the system.

Step 1 – Academic-year planning. The academic affairs office sets the time frame: teaching weeks, sessions, registration periods, examination periods, internships, and holidays.

Step 2 – Demand forecasting and course section opening. Based on the curriculum and learners' academic status, the system forecasts the number of learners for each course and proposes the number of sections; academic faculties review and confirm the proposal. Müller and Rudová [17] have applied the use of curriculum data to forecast demand before registration.

Step 3 – Teaching assignment. Faculties assign lecturers directly in the system, which checks expertise and standard teaching-hour norms.

Step 4 – Timetable and examination scheduling. The system generates options that satisfy all hard constraints and evaluates the degree of soft-constraint satisfaction; schedulers adjust the options interactively, and the system warns immediately if an adjustment causes a conflict. Following the experience of Rudová et al. [16], classes using shared lecture halls, workshops, and laboratories should be scheduled centrally by the university, while other classes are delegated to faculties.

Step 5 – Approval and publication. Timetables are approved electronically and published to learners and lecturers through the web portal and mobile application; all changes after this point are managed in Component 4.

2.9. Schedule implementation management and the monitoring indicator set

After publication, the schedule is affected by many changes: unexpected lecturer absences, equipment failures in rooms, classes cancelled because of insufficient enrolment, and closures due to weather. The model handles these changes according to three principles. First, every change request must be initiated and approved in the system so that the official schedule remains the single source of truth. Second, adjustment options are chosen to minimize disruption to the schedules of the stakeholders concerned, following the approach of Rudová et al. [16]. Third, learners and lecturers are notified automatically as soon as a change takes effect.

For monitoring, the model uses seven indicators (Table 4), divided into three groups: implementation indicators (on-schedule rate, absence and make-up handling time, and grade completion progress); scheduling quality indicators (post-publication adjustment rate and number of conflicts); and resource utilization indicators (room utilization and teaching-load balance). Each indicator is defined by a calculation formula, a data source, and a reporting period. The indicators are calculated automatically from the data of Components 3 and 4, without requiring additional reporting from units.

Table 4. Training schedule monitoring indicators: calculation formulas and data sources

Indicator	Calculation formula	Data source	Reporting period and management purpose
1. On-schedule teaching rate (OS)	OS = Number of periods delivered on schedule up to week t / Number of periods planned up to week t × 100%. An on-schedule period is one confirmed	Official schedule and revised versions (Component 3); electronic	Weekly, by course section; identifies sections falling behind

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Indicator	Calculation formula	Data source	Reporting period and management purpose
	by the lecturer on the date and session specified in the official schedule or an approved revised schedule	teaching-hour confirmation (Component 4)	so that make-up classes can be arranged
2. Post-publication timetable adjustment rate (AR)	AR = Number of approved time, room, or lecturer change requests after the publication date / Total number of course sections × 100 (changes per 100 sections). Broken down by cause: incorrect data; late updates; external events	Change approval workflow log (Component 4)	Per semester; reflects the quality of input data and scheduling
3. Number of conflicts (NC)	NC = Number of hard-constraint violations in the official schedule: lecturer overlaps, room overlaps, learner overlaps, class size exceeding room capacity	Automated constraint checking on the official schedule (Component 3); feedback from learners and lecturers (Component 4)	At publication and weekly; target value is 0
4. Absence and make-up handling time (MT)	MT = Median number of working days from the time an absence is recorded in the system to the time the make-up class is approved and announced	Timestamps of the absence and make-up workflows (Component 4)	Monthly; measures the responsiveness of operations
5. Room utilization (RU)	RU = Total room periods scheduled in the week / (Number of rooms × Available periods per room per week) × 100%; calculated separately by room type	Official schedule (Component 3); room catalogue and maintenance schedules (Component 2)	Per semester; basis for balancing facilities, course opening, and investment
6. Teaching-load balance (LB)	Load ratio of lecturer i: L(i) = Teaching hours delivered / Teaching-hour norm allocated for the semester. LB = Proportion of lecturers whose L(i) lies outside the range set by the university (e.g., 0.8–1.2)	Teaching assignment (Component 3); teaching-hour confirmation (Component 4); standard hour norms (lecturer data)	Monthly and at the end of the semester; avoids load concentration and helps faculties adjust assignments
7. Grade completion progress (GC)	GC = Number of course sections with complete grades entered within the prescribed time after the examination date / Total number of examined course sections × 100%	Examination schedule (Component 3); grade entry log (Component 4)	By examination period; ensures that academic reviews and next-semester registration proceed as planned

Source: Proposed by the author.

To make the indicators comparable across semesters and faculties, three conventions are needed. First, the basic unit of calculation is the course section; faculty- and university-level indicators are aggregated from course-section-level values. Second, indicators are calculated on the versioned official schedule, so an approved change is not counted as a delay but is counted in the adjustment indicator. Third, the first semester with complete data serves as the baseline for comparison in subsequent semesters; for time-based indicators, the number of cases exceeding the threshold should be reported in addition to the median, because the distribution is usually skewed.

Visual dashboards should be designed for each user group. Sarikaya et al. [19] distinguish dashboards for strategic decision-making from those for day-to-day operations. Accordingly, university leaders need aggregated indicators by semester; leaders of the academic affairs office and faculties need weekly indicators together with lists of flagged course sections; and staff need lists of tasks to be handled each day. Alert thresholds are set by the university, for example a course section that is more than one week behind plan without a scheduled make-up class.

2.10. Implementation conditions and roadmap

Implementing the model requires four conditions. Institutionally, the university needs to issue regulations on data responsibility, the constraint set, and the schedule adjustment process. In terms of data, shared catalogues must be cleaned before operation. Technologically, existing academic management software can be used, with missing functions added gradually, without necessarily investing in a new system. In terms of people, academic affairs staff, faculty assistants, and lecturers need training; changing work habits is a greater barrier than technical issues, consistent with the observation of Rodríguez-Abitia and Bribiesca-Correa [9]. On this basis, the roadmap is divided into three phases.

Phase 1 – Standardization of data and processes. Review and unify the codes for courses, classes, lecturers, and rooms; issue the constraint set and the five-step process; and move teaching assignment and the registration of absences and make-up classes to the digital environment. As a result, the official schedule becomes the single source of truth.

Phase 2 – Scheduling support and implementation monitoring. Apply automated constraint checking when scheduling timetables and examinations; introduce electronic teaching-hour confirmation; and calculate the indicators in Table 4 and display them on visual dashboards.

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Phase 3 – Analysis and improvement. Use data accumulated over several semesters to forecast demand for course sections, calibrate soft-constraint weights, optimize room utilization, and evaluate alternative academic-year plans. Fully automated scheduling algorithms should be considered only at this phase, once data and the constraint set have stabilized. The content, outputs, and evaluation criteria for moving between phases are summarized in Table 5.

Table 5. Three-phase implementation roadmap and criteria for moving between phases

Phase	Main content	Outputs	Criteria for moving to the next phase
1. Standardization of data and processes	Unify catalogues and identifiers; issue the constraint set and processes; digitize teaching assignment, absences, and make-up classes	The official schedule is the single source of truth	Move to Phase 2 when all of the following are met: (a) 100% of courses, classes, lecturers, and rooms have identifiers confirmed by the responsible units; (b) the proportion of erroneous records detected by automated data checks at the cut-off date does not exceed 2%; (c) at least 95% of schedule change, absence, and make-up requests in a semester are processed in the system; (d) the regulations on data responsibility, the constraint set, and processes are in force
2. Scheduling support and monitoring	Automated constraint checking; electronic teaching-hour confirmation; indicator calculation and visual dashboards	The indicator set is updated weekly	Move to Phase 3 when all of the following are met: (a) complete implementation data are available for at least two consecutive semesters; (b) at least 90% of class sessions are confirmed electronically; (c) the seven indicators are calculated automatically and match manual reconciliation results on a random sample of course sections; (d) the number of conflicts at publication is 0 for two consecutive semesters
3. Analysis and improvement	Demand forecasting for course sections; weight calibration; room utilization optimization; automated scheduling	Data-based schedule options	Annual evaluation comparing indicators with the baseline; automated scheduling is extended only when system-proposed options do not increase the number of conflicts or the adjustment rate compared with previous practice

Source: Proposed by the author.

The thresholds in Table 5 are reference values illustrating how criteria can be set; each university should determine specific thresholds based on its own baseline. The evaluation for moving between phases should be conducted at the end of each semester by the unit assigned to lead digital transformation, based on reports from the academic affairs office and data reconciliation results. When the criteria have not been fully met, the university should extend the current phase and focus on the unmet criteria instead of deploying functions of the next phase in parallel. This approach is consistent with the principle of redesigning processes before automating them [18] and avoids investing in analytics and optimization before the data are sufficiently reliable.

2.11. Discussion

A comparison with prior studies clarifies the contributions and limitations of the model in three respects.

First, compared with timetabling research, the contribution of the model lies not in algorithms but in how the problem is framed. The reviews by Babaei et al. [14], Chen et al. [15], and Ceschia et al. [7] all note the gap between benchmark and real problems; the proposed model approaches this gap from the governance side by treating data quality, the constraint set issued by the university, and implementation data as conditions for algorithms to be effective. The model is consistent with Rudová et al. [16] in treating post-publication change handling as being as important as initial scheduling and adopts the minimal-perturbation principle; the difference is that the model does not stop at handling individual changes but records changes by cause so that they feed into Loop B. Conversely, the model proposes no improvements to solution methods and does not consider large-scale problems in which many faculties schedule independently, as in the institutions described by Rudová et al. [16] and Müller and Rudová [17].

Second, compared with studies on institution-level digital transformation [3], [9], [10], the model takes the opposite direction: rather than assessing the level of digital transformation of the whole university, it applies Vial's definition [8] to a single task, showing that the task can be transformed in the sequence data–process–indicators without waiting for a comprehensive project. This result is consistent with the view that the main barriers lie in organization and people [9], as reflected in the fact that Phase 1 of the roadmap consists mainly of changes in data responsibility and processes. However, transforming a single task risks creating yet another isolated system if it is not linked to an overall strategy [10]; the shared catalogues in Component 2 should therefore be designed for use by other university functions as well.

Third, compared with works on process management and data analytics [11], [18], [19], the model offers no new method but specializes general methods into a five-step process, seven indicators with calculation formulas, and layered dashboards. This specialization enables the academic affairs office to begin measuring immediately with available data, but it also limits the generalizability of the indicator set to other tasks.

In addition, the model has limitations that should be considered in application. It assumes that the university already has academic management software capable of exporting and importing data; if data are still mainly paper-based, Phase 1 will take considerably longer. Indicators based on self-reported data, such as teaching-hour confirmation, may be misreported, so random reconciliation mechanisms are needed.

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Moreover, because the model was built from published literature, mostly international experience, it does not fully reflect characteristics of Vietnamese universities such as multiple training modes, multiple campuses, or blended online delivery.

The model also raises three issues to be considered in application. First, data on learners and lecturers are personal data; access rights, activity logging, and information disclosure must comply with legal regulations on personal data protection. Second, data-based monitoring of teaching hours may be perceived as a tool for controlling lecturers; the university should make clear that its purpose is to safeguard learners' learning rights and support the arrangement of make-up classes, and should allow lecturers to view their own data. Third, the indicators may conflict with one another; for example, increasing room utilization reduces the capacity to schedule make-up classes. The indicator set should therefore be read as a whole rather than optimizing any single indicator.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1. Conclusions

This paper proposes a six-component model for the digital transformation of developing and managing training schedules at the academic affairs office of a university, connecting source data, data standardization, schedule development, implementation monitoring, analysis and alerts, and decision support through two feedback loops, within and between semesters. Most activities within each component are drawn from studies on timetabling, digital transformation, and process management. The paper's contribution lies in three points: placing schedule development and implementation monitoring within a single data loop, in which implementation data are used to calibrate the following semester; specifying seven monitoring indicators down to calculation formulas and data sources; and developing a three-phase roadmap with explicit criteria for moving between phases, suited to resource-constrained universities.

The study has limitations. The model was built from a synthesis of theory, published international experience, and current regulations; it has not been linked to situational data or validated with operational data from a specific university, so reductions in conflicts, adjustments, or scheduling time have not yet been quantified. The alert thresholds and phase-transition criteria are reference values that need to be calibrated to each university's baseline. Future research should survey the current state of training schedule management at a specific university, such as Hanoi Industrial and Trade University, to establish a baseline; conduct pilots and compare indicators before and after adoption; and examine the acceptance of the model by lecturers, learners, and academic affairs staff.

3.2. Recommendations

Three recommendations follow for universities and their academic affairs offices. First, institutions should start from data and processes rather than from software; a modern scheduling system cannot compensate for incorrect data or processes without clear responsibilities. Second, implementation monitoring should be treated as equal in importance to schedule development, because only implementation data reveal whether a schedule is feasible. Third, outcomes should be measured with specific indicators and shared internally to motivate improvement across faculties.

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