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A Comparative Analysis of Manual and Automatic Timetabling Approaches for Resource Utilisation in Tertiary Higher Learning Institution

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Abstract: This research compares the efficiency and effectiveness of manual versus automated timetabling methods in tertiary higher learning institution (THLI). The study focuses on comparisons of four main aspects: staffing allocation for the creation of the timetable, variety of timetable files created, time spent for creating timetables and classroom utilisation. The results show significant differences between the two approaches. Manual time timetabling approach required a team of 5 to 8 experts, resulting in significant cognitive load and increased likelihood of errors due to iterative adjustments and scheduling complications. In contrast, the automated scheduling approach required only three employees for system setup, maintenance, and validation for the timetable generation significantly reducing human effort post-implementation. In addition, automatic schedule generation created approximately 40 different types of schedule files, providing greater variety and efficiency in resource management, while the manual method only produced three variants. The automated approach significantly reduced the time needed to create timetables, requiring only 3 to 5 days instead of 12 to 15 days with the traditional process. Additionally, classroom utilisation improved significantly, with the manual method achieving less than 40% utilisation while the automated method achieved an efficiency rate of over 95%. The results suggest that automated timetable systems represent a more resource-efficient and effective option compared to manual approaches, enabling improved planning and resource optimization in tertiary higher learning institutions.

Keywords: FET Software; Automatic Timetabling; Manually Timetabling; Genetic algorithm; Academic Institution.

1. Introduction

In the changing field of providing competency-based and quality education, resource planning has emerged as a fundamental element in effectively archiving the objective. Appropriate scheduling ensures optimal utilization of tertiary higher learning institutional resources, including classrooms, laboratories, workshops, enrolled students, academic staff, and administrative staff, to name a few. It facilitates the efficient allocation of essential resources such as time slots, equipment and venues, thereby promoting uninterrupted academic and operational processes.

Resource planning, especially classroom utilization, remains a complicated and resource-intensive undertaking for the personnel involves in timetable generation. Significant labor intensity results from several factors, such as: student choice, teacher availability, space planning, classroom constraints, and institutional constraints. Addressing these challenges requires effective scheduling models that balance stakeholder needs while optimizing resource efficiency. To overcome these challenges, tertiary higher leaning institutions use either manual or automatic timetable techniques.

Despite its widespread use, manual timetabling approach often proves to be laborious and ineffective. Reddy et al. (2021) showed that manual approaches are not suitable for large data sets, complicated constraints, and changing institutional requirements. These approaches are prone to delays, inaccuracies, and rigidity, which limit their effectiveness in dynamic academic environments. Conversely, automated timetable generation (AT) techniques have emerged as effective alternatives, offering improved efficiency through genetic algorithm (GA) solutions. These methods use computational models and optimization techniques to create schedules that take into account various constraints and preferences.

Automated timetable planning minimizes errors, accelerates planning processes and dynamically adapts to changes, making it a useful replacement for paper-based manual methods. Several studies emphasize the advantages of automated scheduling methods. Narang et al. (2013) used GA to create automated schedules and demonstrated its effectiveness in dealing with complicated real-world constraints. Moreira et al. (2008) used genetic algorithms for timetable planning and demonstrated their versatility in meeting various institutional needs. Furthermore, combination of the GA with other techniques resulted in further advances. Abdullah et al. (2008) used GA with local search strategies for course planning, resulting in significant improvements in conflict resolution and optimization. Award et al. (2022) used a combination of GA with dynamic taboo search methods for timetable creation. The results showed that the proposed approaches quickly and efficiently established a schedule while reducing constraint violations. Fernandes et al. (2016) developed decision support systems specifically designed for automated scheduling in higher education and emphasized their applicability in practical academic contexts.

The present study compares the resource utilization for the schedules created by manual and automated schedule generation approaches. The analysis focuses on a tertiary higher learning Institution (THLI). Relevant data collected by researchers is compiled, including the number of programmes offered, the total number of students per programme, modules, number of classrooms, classroom and workshop capacities, and the total number of tutors available. Manual and data-driven AT timetable models are then created for the resource use of specific classrooms at the THLI. Then, the resource utilization effectiveness of AT and manual scheduling is compared and evaluated for each approach.

The novelty of this study lies in its comparative analysis of manual and automatic scheduling techniques for timetabling in THLI, with a focus on optimizing resource utilization. Few studies have explored this comparison, particularly in teaching and higher learning institutions. By emphasizing resource efficiency and practical application, the study provides unique insights to enhance timetabling practices and decision-making in THLIs. A study develops manual and AT models that utilize academic programmes, student enrollments, teaching and learning facilities, and human resources available in the educational institution to develop an accurate resource utilization plan.

The models deliver accurate results while maintaining an efficient balance between computational effort and time, making them ideal for use in various projects. The results of this study will be of great benefit to educational institutions, administrators, and other stakeholders by providing a method for optimizing resource utilization in higher education and enabling informed decision making in addressing planning and resource allocation problems.

2. Methods

2.1 Manual timetabling approach

Manual timetable creation is a traditional planning method that uses human efforts to plan and organize academic or institutional timetables without the help of specialized software (Joyce, 20215; Chaudhary et al., 2016; De et al., 2007; Birbas et al., 2009). It is widely used in educational institutions, particularly those with limited access to digital tools (Wood et al., 1998; Whiteley et al., 2012). In this approach, three schedule developers for the vacancy schedule, program schedule, and faculty/tutor schedule typically meet in the office to develop the schedule based on the given constraints. The same approach is used in the current study to develop the resource utilization comparison schedule. Figure 1 shows the arrangement of manual scheduling practices employed by the study. The proposed approach streamlines the schedule process by synchronizing programmes schedules, vacancy timetables and lecturers timetables to resolve conflicts and optimize resource utilization. It automates the creation and approval of schedules, reducing human errors and saving time. The approach provides an integrated view for improved decision making and ensures adaptability to changes without disruption. Additionally, it increases transparency and ensures a structured, efficient workflow that supports effective management of institutional resources.

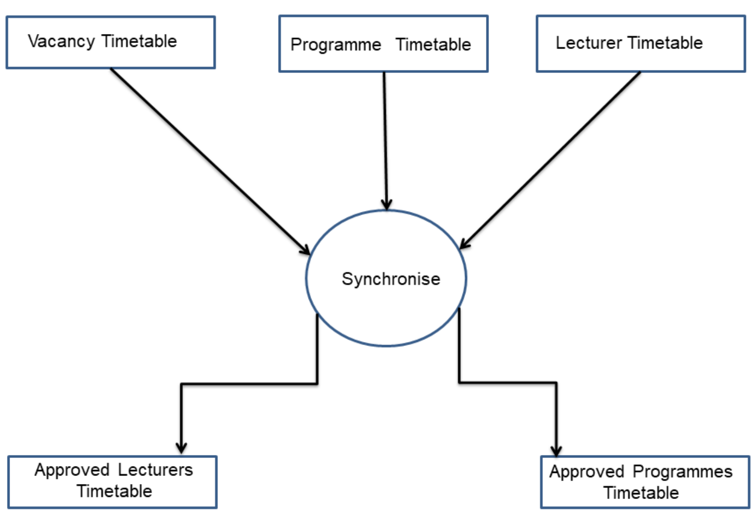


Fig.1. Manually Timetabling Approach

2.2 Automatic Timetabling Approach

Automatic timetable development is the creation of timetables for institutions, organizations or events using algorithms and software tools with the aim of optimizing resource allocation and time management (Aust et al., 1995; Mamatha et al., 2024; Padmini et al., 2010; Khan et al., 2024). It leverages sophisticated computational techniques, including constraint satisfaction algorithms and optimization algorithms, to create conflict-free timetables that take multiple constraints into account, such as: resource availability, participant preferences, and institutional policies. Implementation of AT creation systems requires the integration of input data, including program offerings, teacher or resource availability, and time preferences, into a computer model.

The model processes this data using algorithms to provide optimized timetabless that meet specified requirements, such as: reducing idle time or ensuring fair resource allocation. These solutions increase efficiency, reduce administrative burdens, and improve overall planning accuracy through process automation. Additionally, several modern systems have adaptive features that enable dynamic rescheduling, making them exceptionally proficient in dealing with unforeseen changes such as resource unavailability or scheduling conflicts. A Fig. 2 shows the proposed AT to compare the resource utilization results. The flowchart describes the systematic procedure for creating automated schedules using Free Educational Timetabling (FET) Software employed by the study.

The process begins with data collection, capturing key planning information including programmes offered by the institute, staff availability, student groupings, and space specifications. The next step is to sort the data, categorizing the collected information to make it easier to get started with the program. Restrictions are imposed when entering the sorted data into the FET system. These restrictions are regulations that the schedule must follow. They are categorized into hard constraints (mandatory rules, e.g. to avoid scheduling conflicts) and soft constraints (preferences, e.g. favoring certain time periods). A review is carried out to confirm that all restrictions are accurately defined and meet the specified standards. After checking the constraints, the system creates the schedule.

The schedule created is then checked for compliance with the specified rules and standards. If inconsistencies or errors are found, the procedure returns to adjust the input data or constraints and rebuild the schedule. Once all requirements are met, the schedule will be finalized and published. The final schedule will be distributed to key stakeholders including the Examinations Department, Academic Heads of Departments (HoDs) and Program Class Representatives (CRs) to ensure all parties are informed and synchronized.

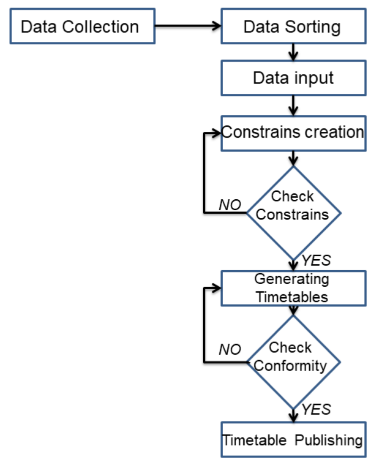


Fig. 2. Proposed Automatic Timetabling Approach

2.3 Resources and data set used

The present investigation used FET software version 6.9.5, executed on a ThinkPad Lenovo personal computer with a 2.71 GHz Core (TM) i7-6820HQ CPU and 32 GB installed RAM. Table 1 displays the input data sets used for constructing the FET model. The datasets obtained from four sources were essential for guaranteeing the precision and dependability of the FET model. Each source supplied distinct and crucial data types required for developing a thorough timetable. Data from academic departments guided the distribution of programmes, students, and modules, whilst the estate office provided information on the capacity of physical resources, including classrooms and labs. Data from the registrar and human resources (HR) departments assured congruence with simulation capabilities and personnel availability. The aggregation of data from many sources guaranteed that the FET model developed comprises an adequately represented real-world situations and facilitated effective and pragmatic scheduling solutions.

Table 1
Descriptions of the resource data set

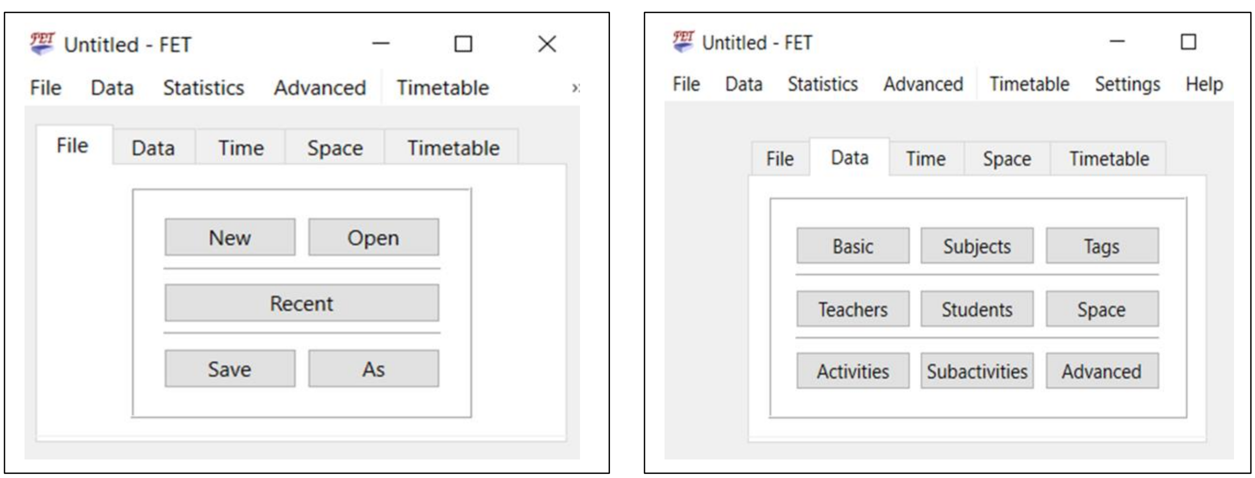
Source of Resource data	Types of Data
Academic Departments	Number of the programmes offered Total number of students per programme Total number of modules
Estate Office	Total number of classrooms Classroom capacity Workshop capacity Marine engine room simulator capacity Computer Laboratory capacity
Registrar Office	Deck room simulator capacity
HR Office	Total number of Lecturer/ Tutor

2.4 *Description of the FET*

FET is a complimentary software application developed to autonomously create timetables for universities, high schools, and educational institutions (Mansor et al., 2013; Muhamad et al., 2018). It employs a prompt and effective scheduling method. A novel heuristic method included into FET emphasises the transition between recurrent tasks, allowing the program to efficiently resolve complex scheduling in a little period. Furthermore, FET accommodates a diverse array of limitations, produces aesthetically pleasing XHTML schedules, and can autonomously manage many groups, such as students, courses and classes.

The present research advocates for the use of FET owing to its distinctive characteristics and benefits compared to other scheduling tools. Initially, FET is entirely free and open-source, making it accessible to organisations with constrained financial resources. The cost-effectiveness is a crucial determinant in its selection. Secondly, FET uses a highly refined algorithm adept in swiftly resolving intricate schedules, even among complicated limitations. This efficiency distinguishes it from several options. Moreover, FET is versatile, accommodating a wide array of scheduling limitations, thereby making it suitable for diverse educational environments and needs. The program excels in automation by accounting for several factors, including student groupings, instructor availability, topic needs, and spatial limitations. This considerably decreases the manual labour necessary for scheduling. Furthermore, the intuitive interface, with systematically arranged choices, enables users to effortlessly enter data and produce schedules without requiring substantial training. Ultimately, FET generates professionally designed XHTML schedules that are comprehensive and aesthetically pleasing, guaranteeing superior deliverables. These benefits provide FET a pragmatic and effective alternative to existing scheduling systems.

The FET interface has seven primary menus: Data, Statistics, File, Time Table, Advanced, Help, and Settings. The Data menu provides the most essential choices, enabling users to enter all required schedule information. Figures 3 (a) and (b) depict the primary menu and the data menu of FET, respectively. Users must enter numerous data, including hours and days, institution information, students, topics, activities, instructors, and spaces under the Data menu. Each menu offers appropriate alternatives to efficiently handle the pertinent data, enabling the seamless creation of schedules according to the institution's individual requirements.



a b

Fig. 3. (a) Main menu and (b) Data Menu

The FET deployment strategy, shown in Fig. 4, delineates a methodical process for a timetable generation, including both sequential and iterative phases. The process starts with data gathering, whereby all necessary institutional information such as number of tutors, classroom availability, and resource needs is compiled. This fundamental step guarantees the accessibility of precise data for the next stages.

The second process, data validation, entails confirming the correctness, completeness, and consistency of the gathered data. This stage guarantees that the information conforms to the institution's standards and mitigates mistakes in subsequent steps. Upon validation, the data advances to the data input phase, during which it is methodically input into the FET system. At this juncture, any discrepancies or deficiencies in the data may be rectified via feedback methods.

The process proceeds with activity creation, which emphasises the definition and organisation of activities, including the allocation of modules to teachers, the scheduling of sessions, and the arrangement of resources. This step lays the groundwork for effective timetable creation. The last step, constraint creation, establishes explicit rules and priorities, including time constraints, resource distribution, and teacher availability/preferences, classroom availability which the FET algorithms use to enhance the timetable.

The timetable generation step use FET's algorithm to create an optimised timetable that satisfies all established limitations and priorities. During the process, feedback loops (shown by the backward arrows) provide iterative modifications, enabling timetable developer to return to previous stages to rectify issues or integrate enhancements. This iterative, bidirectional method guarantees a resilient and effective timetable customised to the institution's particular requirements.

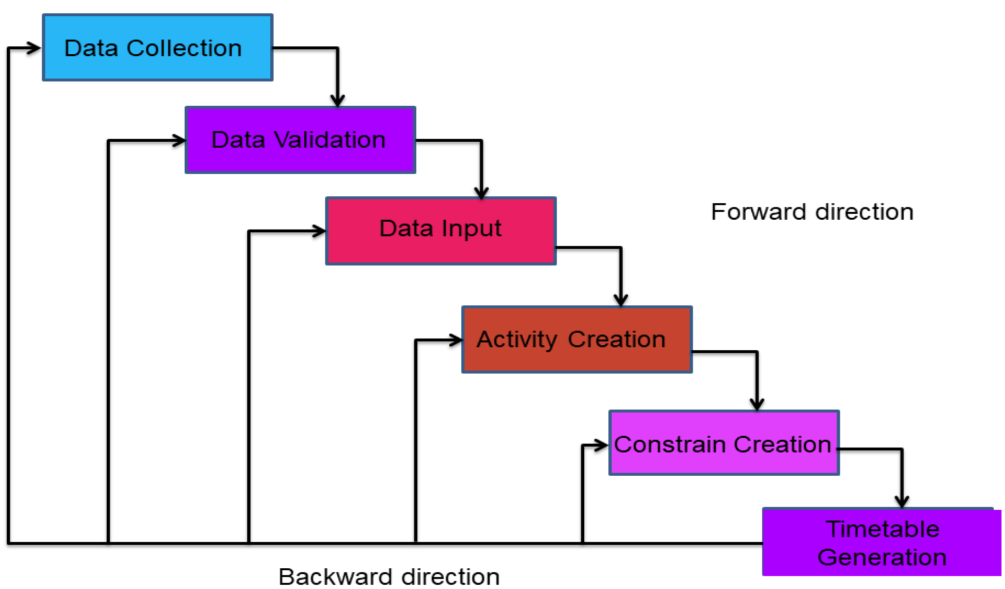


Fig. 4. Deployment strategy for the FET software

2.5 Limitations of the Study

A comparison of manual and automatic timetabling methods yields more intricate scheduling models, requiring substantial computing resources and proficiency in both manual and automated timetabling procedures. Thus, the timetabling models created in this research are tailored for the resource utilisation system of the chosen THLI. Recalibration is necessary prior to its use in diverse THLIs contexts or differing timetable generation circumstances.

2.6 Assumptions and Simplifications of the Proposed Approaches

The suggested timetabling methods rely on numerous fundamental assumptions and simplifications to guarantee their viability and efficacy. Resource availability, including classrooms and teachers, is presumed to be continuous during all schedule times. Furthermore, it is assumed that all resources (e.g., rooms, equipment, and instructors) possess certain guidance on utilization and availability criteria. Moreover, it is assumed that the instructional environment stays constant throughout time, allowing regular scheduling without substantial interruptions. Factors such as fluctuations in resource demand or last-minute schedule modifications have been omitted to streamline the modelling process. These assumptions and simplifications provide a robust basis for comparison on resources utilization using these timetabling strategies to efficiently manage resource allocation, namely classrooms of a selected THLI.

3. Results and Discussion

3.1 A Comparative analysis of the Human Resources Utilised for Automatic and Manual Timetabling Approaches

The research assessed the human resources necessary for scheduling using both automated and manual methods. Multiple validations were performed throughout the timetable creation utilising these procedures to guarantee the required schedules were reached. The research indicated that manual timetabling requires a team of 5 to 8 individuals who dedicate considerable time to iterative modifications, meetings, and the resolution of scheduling issues. This approach imposes a significant cognitive burden on team members and heightens the likelihood of human mistake, especially under deadline timelines. Conversely, automatic timetabling needs just three individuals, whose primary responsibilities are system configuration, upkeep, and validation. Upon becoming operational, the AT system reduces human participation to a single individual, therefore considerably decreasing the time and effort required for validation and reducing the probability of mistakes. The research indicated that manual approaches need significant human resources and effort, while automation optimises the process, providing a more resource-efficient alternative. Notwithstanding early implementation difficulties, including the need for specialised knowledge and reliance on precise data, automated systems eventually enhance human resource allocation, making them a cost-efficient and effective substitute for manual scheduling.

3.2 A Comparative analysis of the Timetable files Generated by Automatic and Manual Timetabling approaches

The study compared the timetable files generated by the automatic and manual timetabling approaches. The study revealed that the manual timetabling approach creating three main types of schedules files: vacancy timetables, lecturer schedules, and programme timetables. Vacancy timetables identify unoccupied time slots for various resources or spaces. Lecture schedules specify the timing and locations for academic sessions, while programme schedules outline academic activities aligned with specific programme. However, the manual method is limited in scope, as it does not provide detailed timetables for individual modules, lecturers, or rooms. Moreover, the process of manually generating these schedules is labour intensive and prone to errors, especially in complex institutions with extensive scheduling needs. In contrast, the automatic timetabling approach offers remarkable versatility and efficiency by generating over 40 types of timetable files. These include specialized schedules for lecturers, individual modules, rooms, and specific activities. The lecturer timetables detail the teaching schedules of department members, while room timetables allocate spaces efficiently for various academic and non-academic activities. Additionally, activity-based timetables cater to specialized or ad hoc events. This level of detail ensures comprehensive planning, improved resource utilization, and conflict-free scheduling. The AT approach also allows for tailored schedules for specific student groups, further enhancing its adaptability and effectiveness.

The results revealed that, the superiority of the AT approach in addressing the scheduling needs of complex systems. Its ability to produce detailed and varied timetable files ensures better coordination and resource management compared to the restrictive and less efficient manual method. This comparison highlights the potential of automatic timetabling systems to transform scheduling processes in educational and organizational environments.

3.3 A Comparative analysis of time utilised by Utilised by Automatic and Manual Timetabling Approaches

The research compared the duration needed to produce satisfactory timetables using two distinct methods: the manual timetabling technique and the automated timetabling technique. The comparison sought to highlight the efficacy and time-saving capabilities of each approach in timetable generation. The measuring period began directly after the data collecting step and continued until the schedule publication phase. This enabled a thorough assessment of the overall time used by each technique, including all intermediary activities involved in schedule formulation. The results indicated a substantial disparity in the duration required by the two methodologies. The human timetabling method needed 12 to 15 days for completion, but the automated timetabling method required just between 3 to 5 days. This outcome highlights the efficacy of the automated approach in reducing the duration required for schedule creation.

3.4 A Comparative analysis of Classroom utilisation by Timetables Produced by Automatic and Manual Timetabling Approaches

A research examined classroom utilisation by contrasting timetables produced via manual and automatic timetabling techniques. The study focused on classrooms accommodating 200 students. A 200 classrooms capacity was chosen as a benchmark for resource utilisation due to its prevalence in many programmes, making it a common and pragmatic criterion for assessment. Utilisation was assessed by calculating the ratio of occupied classroom hours to the total available weekly hours, totalling 65 hours.

The findings demonstrated a significant disparity between the two scheduling techniques as indicated by Fig. 5 (a) and (b) for the generated timetable for manual and AT approaches respectively. Manually generated timetables Fig. 5 (a) led to classroom utilisation rates below 40%, underscoring inefficiencies in spatial and temporal management. Conversely, automatic scheduling Fig. 5 (b) attained an utilisation rate of 95%, illustrating its efficacy in optimising classroom resources. The results highlight the benefits of automated timetabling systems, especially for programmes with large student enrolments, and their capacity to enhance resource efficiency in educational institutions.

HALL 2 (200)

DAY / TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
0800 – 0900 0900 – 1000	SMT 04225 Logistics integration and Operation Management Programme Lecturer		MET 05204 Elementary Technical Drawing Programme Lecturer	MET 04208 Freehand Drawing BTCNAOE Programme Lecturer	SMT 04226 Fundamental Principles of Supply Chain Management Programme Lecturer
1000 – 1100 1100 – 1200	SMT 04227 Introduction to Inventory and Warehousing Management Programme Lecturer	SMT 04229 Business Numeracy Programme Lecturer	MNT 06207 Basics of Port Operations ODMTNS/ODME Programme Lecturer	SMT 04229 Business Numeracy BTCPLSM+BTCTSM Programme Lecturer	SMT 04228 Legal Aspect of Business Logistics Programme Lecturer
1200 – 1300					
1300 – 1400 1400 – 1500	SMT 04228 Legal Aspect of Business Logistics Programme Lecturer			MET 05204 Elementary Technical Drawing TCME Eng. S. Mziray	MET 04208 Freehand Drawing BTCNAOE Eng. S. Mziray
1500 – 1600 1600 – 1700		SMT 04227 Introduction to Inventory and Warehousing Management Programme Lecturer	MEU 07209 Marine Engineering Watchkeeping Programme Lecturer	SMT 04226 Fundamental Principles of Supply Chain Management Programme Lecturer	MMU 07434 Engineering Dynamics Programme Lecturer
1700 – 1800 1800 – 1900	SMU 07240 Procurement Negotiation Skills Programme Lecturer		SMU 08226 Public Procurement Programme Lecturer		
1900 – 2000					
2000 – 2100					

(a)

	HALL 2 [200]				
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
08:00 - 09:00 **09:00 - 10:00**	Programme-Lecturer SLT 05105 Customers Services and Quality Management	Programme-Lecturer SLT 05105 Customers Services and Quality Management	Programme-Lecturer SLU 08102 Supply Chain Design	Programme-Lecturer SLT 04102 Transport Geography	Programme-Lecturer SLT 04105 Arithmetic, Indices and Algebra
10:00 - 11:00 **11:00 - 12:00**	Programme-Lecturer SLT 05103 Computer Applications	Programme-Lecturer MEU 07317 Marine Diesel Engines and Turbines	Programme-Lecturer SLT 04107 Basics of Communication Skills	Programme-Lecturer SLT 04107 Basics of Communication Skills	Programme-Lecturer SLU 07107 Logistics and Multimodal Transport
12:00 - 13:00 **13:00 - 14:00**	Programme-Lecturer OGU 07326 Well logging and formation and evaluation	Programme-Lecturer OGU 07326 Well logging and formation and evaluation LECTURE	Programme-Lecturer MEU 07106 Principles of Calculus	Programme-Lecturer SLU 07322 Development Studies	Programme-Lecturer SLU 08101 Charter Party and Bill of Lading
14:00 - 15:00 **15:00 - 16:00**	Programme-Lecturer OGU 07319 Communication Skills	Programme-Lecturer SLU 07105 Communication Skills	Programme-Lecturer SLT 05102 Management of Shipping Operations	Programme-Lecturer MEU 07146 Communication Skills for Engineers	Programme-Lecturer SLU 08104 Shipping Investment Appraisals
16:00 - 17:00 **17:00 - 18:00**	Programme-Lecturer MEU 07315 Thermodynamics and Heat Transfer	Programme-Lecturer MEU 07316 Electric Circuits	Programme-Lecturer SLU 08106 Business Ethics and Corporate Governance	Programme-Lecturer MEU 07148 Engineering Statics	Programme-Lecturer SLU 07322 Development Studies
18:00 - 19:00			---	Programme-Lecturer SLU 08105 Statistics and Probability	Programme-Lecturer MEU 07315 Thermodynamics and Heat Transfer
19:00 - 20:00 **20:00 - 21:00**	Programme-Lecturer SLU 07102 Engineering Knowledge for Ships	---	Programme-Lecturer SLT 05103 Computer Applications	---	
	Timetable generated with FET 6.9.5 on 11/20/23 10:13 PM				

(b)

Fig. 5. Timetable generated by AT and Manual Approaches

4. Conclusion

A comparative analysis was conducted to evaluate the efficiency and effectiveness of manual and automatic timetabling approaches in educational institutions. The study assessed multiple aspects, including human resource utilization, the variety of timetable files generated, time efficiency, and classroom utilization. The results revealed significant differences between the two methods. Manual timetabling required a team of 5 to 8 individuals, with considerable time and effort dedicated to iterative modifications, resulting in higher cognitive burden and a greater risk of errors. In contrast, automatic timetabling required fewer personnel just three individuals for system configuration, upkeep, and validation and significantly reduced human involvement after system implementation. The study revealed that an automation timetable approach led to a more resource efficient with reduced human error.

Furthermore, a study recognises that the manual approach generated only three main types of timetable files, whereas the automatic method produced over 40 different types, providing greater versatility and efficiency in resource management. These timetables files are including detailed schedules for lecturers, modules, rooms, and specific activities with better coordination and conflict-free. Also, the time taken to produce satisfactory timetables was considerably reduced with the automatic approach, requiring only 3 to 5 days compared to 12 to 15 days for the manual process.

In terms of classroom utilization, the manual method resulted in less than 40% efficiency, while the automatic method achieved above 95% utilization, demonstrating a remarkable improvement in resource allocation. The study concludes that automatic timetabling systems offer significant advantages over manual methods, including reduced time, better resource management, and enhanced efficiency, particularly in complex educational environments with large scheduling demands. The findings suggest that automation can transform scheduling processes, providing a more cost-effective and effective solution for educational institutions.

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Declaration of competing interest

The authors confirm that no discernible conflicting financial interests or personal relationships influenced the research in this study.

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