Tabu Search [1], Variable Neighborhood Search [2], Simulated Annealing [4], Ant Colony Optimization [5], Branch-and-price Algorithm [6], Harmony Search [7, 8] and Scatter Search [9]. More details about some of these methods can be seen in [10], and [11].

1. E. K. Burke, G. Kendall, and E. Soubeiga, "A tabu-search hyperheuristic for timetabling and rostering," Journal of Heuristics, vol. 9, pp. 451-470, 2003.
2. B. Bilgin, P. De Causmaecker, B. Rossie, and G. V. Berghe, "Local search neighbourhoods for dealing with a novel nurse rostering model," Annals of Operations Research, vol. 194, pp. 33-57, 2012.
3. M. J. Brusco and L. W. Jacobs, "Cost analysis of alternative formulations for personnel scheduling in continuously operating organizations," European Journal of Operational Research, vol. 86, pp. 249-261, 1995.
4. W. J. Gutjahr and M. S. Rauner, "An ACO algorithm for a dynamic regional nurse-scheduling problem in Austria," Computers & Operations Research, vol. 34, pp. 642-666, 2007.
5. B. Maenhout and M. Vanhoucke, "Branching strategies in a branchand-price approach for a multiple objective nurse scheduling problem," Journal of Scheduling, vol. 13, pp. 77-93, 2010.
6. M. A. Awadallah, A. T. Khader, M. A. Al-Betar, and A. L. a. Bolaji, "Global best Harmony Search with a new pitch adjustment designed for Nurse Rostering," Journal of King Saud University-Computer and Information Sciences, vol. 25, pp. 145-162, 2013.
7. M. A. Awadallah, A. T. Khader, M. A. Al-Betar, and A. L. a. Bolaji, "Harmony search with greedy shuffle for nurse rostering," International Journal of Natural Computing Research (IJNCR), vol. 3, pp. 22-42, 2012
8. E. K. Burke, T. Curtois, R. Qu, and G. V. Berghe, "A scatter search methodology for the nurse rostering problem," Journal of the Operational Research Society, vol. 61, pp. 1667-1679, 2010
9. B. Cheang, H. Li, A. Lim, and B. Rodrigues, "Nurse rostering problems––a bibliographic survey," European Journal of Operational Research, vol. 151, pp. 447-460, 2003.

Properly scheduling the nursing staff has a great impact on the quality of health care (Oldenkamp, 1996)

J.H. Oldenkamp, Quality in Fives: On the Analysis, Operationalization and Application of Nursing Schedule Quality, University of Groningen, 1996.

Due to these constraints, the solution search space of nurse rostering problems is highly constrained with feasible regions usually disconnected. Besides, it has been proven that nurse rostering problem is among the class of non-polynomialtime hardness (NP-hard)

Scheduling nurses in hospitals is a complex problem due to variability in demand and a variety of conflicting interests and objective

(E. K. Burke, 2003)

In the dynamic realm of healthcare management, the nurse rostering problem has emerged as a critical challenge, demanding innovative solutions to optimize workforce scheduling and enhance overall operational efficiency. Properly scheduling the nursing staff has a great impact on the quality of health care (Oldenkamp, 1996), the recruitment of nursing personnel, the development of a nursing budgets and various other functions of the nursing service (Cheang et al., 2003). The problem involves producing daily schedules for nurses over a given time horizon, it consists in generating daily (or weekly) schedules for nurses by assigning a number of daily (or weekly) demanding shifts to nurses with different skills in order to satisfy certain predefined hard and soft constraints. The objectives are to improve the hospitals’ efficiency, to balance the workload among nurses and, more importantly, to satisfy various hard constraints, and as many soft constraints as possible, such as minimal nurse demands, “day-off” requests, personal preferences, etc.

The dynamic landscape of healthcare management necessitates constant adaptation to meet the evolving demands of patient care. Nurse scheduling within hospitals stands as a pivotal component in this intricate web of healthcare operations. The historical context reveals a growing need for efficient nurse rostering systems, influenced by the increasing complexity of healthcare delivery, legal regulations, and the balancing act between limited resources and burgeoning patient demands. The integration of intelligent software tools into nurse scheduling practices marks a promising avenue for addressing these challenges, thereby enhancing overall healthcare service delivery.

However, scheduling nurses have always proven difficult due to the fact that hospitals need to be staffed 24 hours a day over 7 days a week, therefore, nursing officers spend a substantial amount of time developing rosters especially when there are many staff requests, and where even more time can be consumed in handling ad hoc changes to current duty rosters due to varying conflicting interests and objectives. Additionally, the ever-changing nature of healthcare environments exacerbates the complexity of nurse rostering, demanding adaptive and intelligent solutions capable of optimizing schedules in real-time.

Despite the critical role of nurse scheduling, various challenges persist within this domain. These challenges include the need to balance to satisfy various hard constraints such as legal requirements, staff preferences, and institutional regulations, and as many soft constraints as possible, such as minimal nurse demands, “day-off” requests, personal preferences, etc. Traditional scheduling methods often struggle to efficiently navigate these multifaceted constraints, resulting in suboptimal nurse schedules that can lead to decreased staff satisfaction, increased burnout, and ultimately, compromised patient care. Additionally, the ever-changing nature of healthcare environments exacerbates the complexity of nurse rostering, demanding adaptive and intelligent solutions capable of optimizing schedules in real-time.

Despite the growing interest in intelligent scheduling tools, there exists a research gap in the comparative analysis of specific optimization techniques, such as Ant Colony Optimisation (ACO) hyper-heuristic schemes, for nurse scheduling. While ACO has been applied to various optimization problems, its application to nurse scheduling remains relatively unexplored. This project aims to bridge this gap by proposing an intelligent software tool that utilizes two distinct ant colony optimization hyper-heuristic schemes for nurse scheduling. Drawing inspiration from successful applications of similar approaches in related domains, this proposed solution seeks to demonstrate its efficacy in handling the intricate constraints of nurse rostering and addressing the specific challenges within the nurse scheduling domain

. By leveraging the success of ACO in other domains and similar optimization problems, there is a potential

A conspicuous research gap exists in the exploration of advanced optimization techniques for nurse scheduling problems, particularly in the context of ant colony optimization hyper-heuristic schemes. While ACO has been applied to various optimization problems, its application to nurse scheduling remains relatively unexplored. By leveraging the success of ACO in other domains and similar optimization problems, there is a potential to address the specific challenges within the nurse scheduling domain.

Due to the amount of limitations, the solution search space of nurse rostering problems is tightly constrained and often characterized by disjointed feasible regions. And it has also been proven that the problem space has been characterized in the class of Non-Polynomial-time hardness (NP-hard), meaning, no algorithm can surely find an optimal solution in polynomial time unless P = N. ). These approaches can be classified in two major categories: deterministic algorithms and heuristics. The first category's main disadvantage lies in its high computational complexity which limits their application only to small size instances, and when attempted to be scaled, either cost too much computation, or have difficulty in constraint handling

While in healthcare, a comprehensive analysis reveals that the existing works often fall short in effectively addressing the intricacies of nurse rostering problems. The proposed research acknowledges the limitations of current methodologies and positions itself as a novel contribution to the field. By employing a comparative study of two ant colony optimization hyper-heuristic schemes, this project seeks to shed light on the nuanced performance differences and guide the development of more robust and adaptive nurse scheduling tools.

Existing works in the field have primarily focused on traditional scheduling methods or have explored single heuristic or metaheuristic approaches. The opportunity lies in the comparative evaluation of multiple ACO hyper-heuristic schemes, which has not been extensively addressed in the context of nurse scheduling. Methodologically, this study presents an opportunity to fill this gap by rigorously comparing the performance of distinct ACO hyper-heuristic schemes in the context of nurse scheduling.

Over the years, various scheduling algorithms have been employed by researchers to solve this problem. These methods include Tabu Search (Burke, Kendall, & Soubeiga 2003), Variable Neighborhood Search (Bilgin et al., 2012), Simulated Annealing (Brusco & Jacobs, 1995), Ant Colony Optimization (Gutjahr, & Rauner, 2007), Branch-and-price Algorithm (Maenhout, & Vanhoucke, 2010), Harmony Search (Awadallah et al., 2013) and Scatter Search (Curtois & Berghe, 2010. A comprehensive analysis reveals that the existing works often fall short in effectively addressing the intricacies of nurse rostering problems, and whose main disadvantage lies in its high computational complexity which limits their application only to small size instances, and when attempted to be scaled, either cost too much computation, or have difficulty in constraint handling. Therefore, alternative optimization methods, namely heuristics and metaheuristics have been developed in order to find suboptimal solutions of good quality in a reasonable time.

Existing works in this field have primarily focused on traditional scheduling methods or have explored single heuristic or metaheuristic approaches. The opportunity lies in the comparative evaluation of multiple ACO hyper-heuristic schemes, which has not been extensively addressed in the context of nurse scheduling. Methodologically, this study presents an opportunity to fill this gap by rigorously comparing the performance of distinct ACO hyper-heuristic schemes in the context of nurse scheduling.

The hypothesis of this study is that the comparative analysis of two ACO hyper-heuristic schemes will reveal significant differences in their effectiveness for nurse scheduling. This approach is significant as it aims to provide empirical evidence to support the selection of the most suitable ACO hyper-heuristic scheme for nurse scheduling, thereby improving the efficiency and fairness of the scheduling process. In summary, this research seeks to address the existing gaps in nurse scheduling methodologies and to contribute to the advancement of intelligent software tools for nurse scheduling, ultimately enhancing both staff satisfaction and the quality of patient care.

We hypothesize that the comparative study of two ant colony optimization hyper-heuristic schemes for nurse scheduling will uncover varying levels of effectiveness in optimizing nurse schedules within hospital settings. This research holds significant promise in providing valuable insights into the optimal strategies for nurse rostering, contributing to enhanced patient care, improved staff satisfaction, and overall operational efficiency within healthcare institutions. The proposed intelligent software tool represents a pioneering approach to addressing the existing gaps in nurse scheduling methodologies, marking a crucial step towards the advancement of healthcare management systems.

The intricate landscape of nurse scheduling within hospital management is characterized by the challenging task of balancing legal regulations, staff preferences, and institutional constraints. Despite a growing interest in intelligent scheduling tools, a critical research gap exists, particularly in the exploration and comparative analysis of optimization techniques tailored for nurse scheduling. Current methods often fall short in efficiently navigating these multifaceted constraints, resulting in suboptimal nurse schedules that may compromise patient care and staff satisfaction. The overarching problem lies in the absence of a comprehensive understanding of the effectiveness of specific optimization techniques, such as Ant Colony Optimization (ACO) hyper-heuristic schemes, in addressing the nuanced complexities of nurse scheduling within the dynamic healthcare environment.

The problem in the domain of nurse scheduling in hospitals is the inefficient and time-consuming manual scheduling process characterized by the challenging task of balancing legal regulations, staff preferences, and institutional constraints, which often leads to suboptimal schedules and resource allocation. This can result in decreased staff satisfaction, increased burnout, and ultimately, compromised patient care. The traditional scheduling methods have not been able to address the specific challenges within the nurse scheduling domain, and existing works have primarily focused on single heuristic or metaheuristic approaches. The overarching problem lies in the absence of a comprehensive understanding of the effectiveness of specific optimization techniques, such as Ant Colony Optimization (ACO) hyper-heuristic schemes, in addressing the nuanced complexities of nurse scheduling within the dynamic healthcare environment.

To address the identified research gap, this study proposes an innovative solution through a comparative analysis of ACO hyper-heuristic schemes. By leveraging insights gained from related domains and successful applications of similar approaches, the research aims to unveil the nuanced performance differences between the identified ACO hyper-heuristic schemes, providing empirical evidence to support the selection of the most suitable ACO hyper-heuristic scheme for nurse scheduling. The objective is to develop an intelligent software tool specifically tailored for nurse scheduling, enhancing adaptability and efficiency within hospital settings. Through this exploration, the study seeks to contribute valuable insights and advancements that can significantly improve patient care, staff satisfaction, and the overall operational efficiency of healthcare institutions.

The proposed solution to the problem is the development of an intelligent software tool for scheduling nurses in hospitals using two ACO hyper-heuristic schemes. The comparative analysis of these schemes will reveal significant differences in their effectiveness for nurse scheduling, providing empirical evidence to support the selection of the most suitable ACO hyper-heuristic scheme for nurse scheduling. This will improve the efficiency and fairness of the scheduling process, ultimately enhancing both staff satisfaction and the quality of patient care. The success of ACO in other domains and similar optimization problems presents a potential solution to the specific challenges within the nurse scheduling domain.

1. Literature review: A comprehensive literature review will be conducted to identify existing scheduling methods and optimization techniques, including ACO hyper-heuristic schemes, in the context of nurse scheduling. This will help to establish the scope and depth of the project, contribute to the research design, and indicate how the project will contribute to existing knowledge.
2. Software development: An intelligent software tool for nurse scheduling will be developed using two ACO hyper-heuristic schemes. The software will be designed to optimize the scheduling process, improve efficiency, fairness, and resource allocation.
3. Performance evaluation: The performance of the two ACO hyper-heuristic schemes will be evaluated in terms of efficiency, fairness, and resource allocation. The results will be compared to identify the most suitable scheme for nurse scheduling.
4. Empirical evidence: The study will provide empirical evidence to support the selection of the most effective ACO hyper-heuristic scheme for nurse scheduling. This will be achieved by comparing the results of the two schemes and demonstrating how the selected scheme improves the efficiency and fairness of the scheduling process, ultimately enhancing both staff satisfaction and the quality of patient care.
5. SMART objectives: The study will use SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) objectives to ensure that the research is focused, achievable, and contributes to the advancement of knowledge in the field. The objectives will be clearly stated, and appropriate verbs will be used to accurately characterize the work that will be carried out.

A comprehensive literature review will be conducted to identify existing scheduling methods and optimization techniques, including ACO hyper-heuristic schemes, in the context of nurse scheduling.

An intelligent software tool for nurse scheduling will be developed using two ACO hyper-heuristic schemes. The software will be designed to optimize the scheduling process, improve efficiency, fairness, and resource allocation

The performance of the two ACO hyper-heuristic schemes will be evaluated in terms of efficiency, fairness, and resource allocation. The results will be compared to identify the most suitable scheme for nurse scheduling.

The study will provide empirical evidence to support the selection of the most effective ACO hyper-heuristic scheme for nurse scheduling. This will be achieved by comparing the results of the two schemes and demonstrating how the selected scheme improves the efficiency and fairness of the scheduling process, ultimately enhancing both staff satisfaction and the quality of patient care.

The significance of this study lies in its potential to revolutionize nurse scheduling practices within hospital management, offering substantial benefits to healthcare institutions, nursing staff, and ultimately, the quality of patient care. The study's significance can be outlined as follows:

Healthcare managers and decision-makers stand to benefit from the study's recommendations and guidelines for implementing the intelligent software tool. The insights gained from the research can inform strategic decision-making and demonstrate the applicability of advanced scheduling technologies like ACO hyper-heuristic schemes in solving complex optimization problems, aiding in the adoption of these technologies and methodologies in various domains.

The study will demonstrate the applicability of ACO hyper-heuristic schemes in solving complex optimization problems, such as nurse scheduling, thereby promoting their adoption in various domains.

This study will contribute to the advancement of knowledge in the field by comparing the performance of two ACO hyper-heuristic schemes for nurse scheduling.

The study adds to the academic discourse on nurse scheduling optimization, particularly in the context of ACO hyper-heuristic schemes

The study will demonstrate the applicability of ACO hyper-heuristic schemes in solving complex optimization problems, such as nurse scheduling, thereby promoting their adoption in various domains

This study will contribute to the advancement of knowledge in the field by comparing the performance of two ACO hyper-heuristic schemes for nurse scheduling

The proposed intelligent software tool, has the potential to significantly improve the efficiency of nurse scheduling. By optimizing schedules in real-time and adapting to dynamic healthcare environments, the tool aims to streamline operational processes, leading to better resource utilization and overall operational efficiency.

A comprehensive literature review will be conducted on existing literature related to nurse scheduling, optimization techniques, and ACO hyper-heuristic schemes and will be used to identify existing scheduling methods, optimization techniques, and ACO hyper-heuristic schemes in the context of nurse scheduling.

Design and implement two distinct ACO hyper-heuristic schemes for nurse scheduling, incorporating insights from the literature review and considering the specific constraints of the healthcare environment. Utilize appropriate programming languages and tools to develop the intelligent software tool, ensuring user-friendly interfaces and compatibility with healthcare management systems.

The intelligent software tool for nurse scheduling will be developed using the Java programming language. The software will be designed to optimize the scheduling process, improve efficiency, fairness, and resource allocation.

Designing the software tool to optimize the scheduling process and improve efficiency and developing said software tool using

Developing the software tool using programming languages like Java to implement the selected ACO hyper-heuristic schemes.

The evaluation will be conducted using simulation tools such as MATLAB or R. The results will be compared to identify the most suitable scheme for nurse scheduling.

Employ statistical methods to compare the results obtained from the two ACO hyper-heuristic schemes, evaluating them using simulation and visualization tools like MATLAB or R to represent and compare the output, with the intention of providing a clear understanding of the performance variations and identification of the most suitable scheme for nurse scheduling.

The study will provide empirical evidence to support the selection of the more effective ACO hyper-heuristic scheme by comparing the results of the two schemes for nurse scheduling and demonstrating how the selected scheme improves the efficiency and fairness of the scheduling process.