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\documentclass[12pt,a4paper]{article}
\usepackage[utf8]{inputenc}
\usepackage{geometry}
\usepackage{setspace}
\usepackage{titlesec}
\usepackage{lmodern}
\usepackage{fancyhdr}
\usepackage{graphicx}
\usepackage{parskip}

\geometry{margin=1in}
\setstretch{1.5}
\raggedbottom  % Prevents LaTeX from stretching vertical spacing to fill pages

% Title formatting
\titleformat{\section}{\normalfont\Large\bfseries}{\thesection.}{1em}{}

% Start document
\begin{document}

% Title Page
\begin{titlepage}
   \centering
   \vspace*{3cm}
   {\Huge \bfseries Optimizing Distribution Scheduling for Ice Bath Tanks Using AI-Based Analytics\par}
   \vspace{2cm}
   {\Large Abishai Srinivasan\par}
   \vspace{0.5cm}
   RWTH Aachen University, Data Analytics and Decision Science \\
   abishai.srinivasan@rwth-aachen.de \\
   \vfill
   {\large May 31, 2025}
\end{titlepage}

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\newpage

% Abstract
\section*{Abstract}
Ice Bath Tanks GmbH faces significant challenges in scheduling deliveries due to strict customer time windows, regulated working hours for drivers, and the need for multiple drivers at certain installations. These constraints result in high distribution costs that threaten the company's profitability. This paper proposes an AI-based scheduling model that optimizes delivery routes and workforce assignments, aiming to reduce costs and improve operational efficiency. The model leverages mixed-integer programming and metaheuristic algorithms to adapt to dynamic changes. The approach is expected to deliver substantial cost savings and enhance customer satisfaction.

Submitted: May 31, 2025
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% Introduction
\section{Introduction}
Ice Bath Tanks GmbH is a leading German company specializing in the sale and installation of cold water tanks for ice baths. The company has experienced rapid growth, with sales reaching €15 million in 2024, a result of increasing consumer interest in wellness trends such as the Wim Hof method. To manage this expansion, Ice Bath Tanks has successfully implemented machine learning models for customer demand forecasting, fleet optimization, and workforce allocation. Despite these advances, distribution scheduling remains a major challenge.

The primary difficulty lies in the complexity of delivery scheduling. Customers require deliveries within specific, often narrow time windows, and drivers must adhere to strict regulations regarding working hours. Furthermore, some installations require the presence of multiple drivers. These factors combine to drive up distribution costs and threaten the company's profit margins.

The purpose of this paper is to propose an AI-driven scheduling approach that optimizes delivery routes and workforce assignments, thereby reducing costs and improving operational efficiency. The remainder of this paper is organized as follows. Section 2 reviews relevant literature on scheduling and optimization. Section 3 provides a precise description of the problem and its constraints. Section 4 outlines the proposed AI-based scheduling model and its algorithmic framework. Section 5 discusses the expected benefits and potential limitations. Finally, Section 6 summarizes the findings and suggests directions for future research.

% Literature Review
\section{Literature Review}
Several approaches to scheduling and optimization have been studied in the literature. Traditional methods, such as heuristic algorithms and linear programming, have been widely used in logistics and supply chain management. More recently, AI techniques—including machine learning and metaheuristics—have been applied to complex scheduling problems, demonstrating significant improvements in efficiency and cost reduction. For example, recent studies have shown that AI-based scheduling can effectively handle time window constraints and workforce regulations in delivery operations. This paper builds on these advances by tailoring AI techniques to the specific needs of Ice Bath Tanks GmbH.

% Problem Description
\section{Problem Description}
The core of the scheduling problem at Ice Bath Tanks GmbH is to assign delivery routes and workforce to customer orders while respecting the following constraints:

\begin{itemize}
    \item \textbf{Customer time windows:} Each customer specifies a preferred delivery time slot.
    \item \textbf{Worker regulations:} Drivers have regulated working hours and may not exceed legal limits.
    \item \textbf{Multi-driver requirements:} Some installations require the simultaneous presence of multiple drivers.
\end{itemize}

Let CC denote the set of customers, each with a time window $[t_i, t_j]$ for delivery. Let DD denote the set of available drivers, each with a maximum working duration W_a. The objective is to minimize total distribution costs, which include travel time and labor costs, while satisfying all constraints.

% Proposed AI-Based Scheduling Model
\section{Proposed AI-Based Scheduling Model}
The proposed model leverages recent advances in AI and optimization to address the scheduling problem. The approach consists of the following steps:

\begin{itemize}
    \item \textbf{Data Collection:} Gather information on customer orders, time windows, and driver availability.
    \item \textbf{Model Formulation:} Use mixed-integer programming (MIP) to model the problem, incorporating all constraints.
    \item \textbf{Algorithm Design:} Apply a metaheuristic algorithm, such as genetic algorithms or simulated annealing, to efficiently search for high-quality solutions.
    \item \textbf{Implementation:} Integrate the algorithm into the company's existing IT infrastructure for real-time scheduling.
\end{itemize}

The algorithm is designed to adapt to dynamic changes, such as new orders or driver absences, ensuring robust performance in real-world conditions.

% Expected Benefits
\section{Expected Benefits}
The proposed AI-based scheduling model is expected to deliver several benefits:

\begin{itemize}
    \item \textbf{Reduced distribution costs:} By optimizing routes and workforce assignments, the model minimizes travel time and labor expenses.
    \item \textbf{Improved customer satisfaction:} Meeting customer time windows more reliably enhances service quality.
    \item \textbf{Operational efficiency:} The model enables better utilization of resources and reduces idle time for drivers.
\end{itemize}

Potential limitations include the need for accurate input data and the computational complexity of solving large-scale instances. However, these challenges can be mitigated through careful data management and the use of efficient algorithms.

% Conclusions and Outlook
\section{Conclusions and Outlook}
This paper has presented an AI-based approach to optimize distribution scheduling for Ice Bath Tanks GmbH. The proposed model addresses the company's specific constraints and is expected to deliver significant cost savings and operational improvements. Future research could explore the integration of real-time data streams and the extension of the model to include additional constraints, such as vehicle capacity and maintenance schedules.

% Bibliography
\section*{Bibliography}
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\end{itemize}

\end{document}