The Implementation of a Digital Supply Chain Twinning on the Enterprise

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College of Engineering

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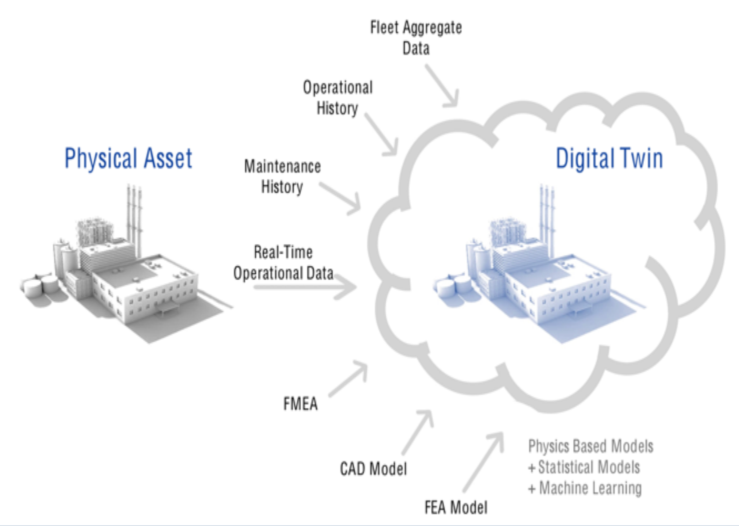
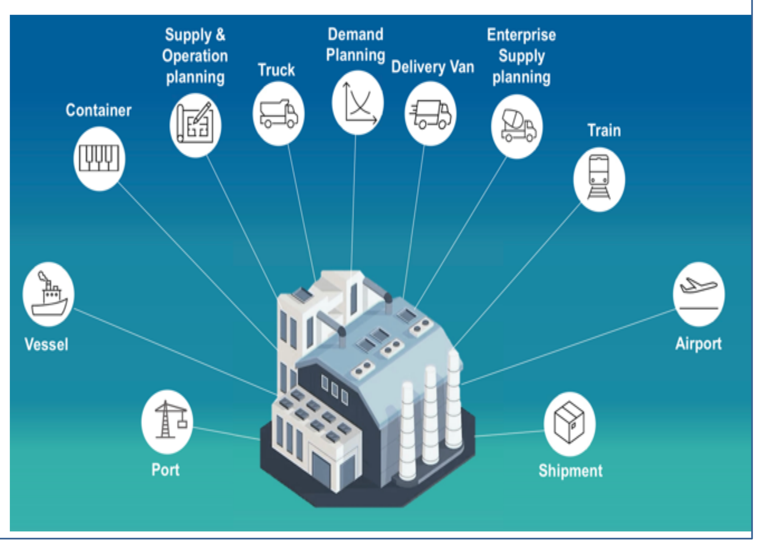
Abstract

Today's supply chain is becoming complex and fragile. Adaptive and highly synchronized supply chains can mitigate ripple effects caused by cascading inventory dynamics. Smart digital supply chains need integration, visibility, agility, and connectivity. NUPCO, a health care supply chain entity serving the Kingdom of Saudi Arabia, is facing multiple gaps in running it's supply chain operations namely overstocking, slow supplying operations, and integration and connectivity of its suppliers. To address this issue, we aim to develop a digital twin framework, an industry 4.0 tool, that uses real-time data to forecast NUPCO's supply chain dynamics. The digital twin simulates multiple scenarios and will help NUPCO derive tactical and strategic decisions. The proposed system not only will help NUPCO in filling their system gaps, but also drive operational efficiency and improve their productivity with the help of advanced technologies as artificial intelligence and machine learning providing them with greater visibility across their supply chains.

Introduction

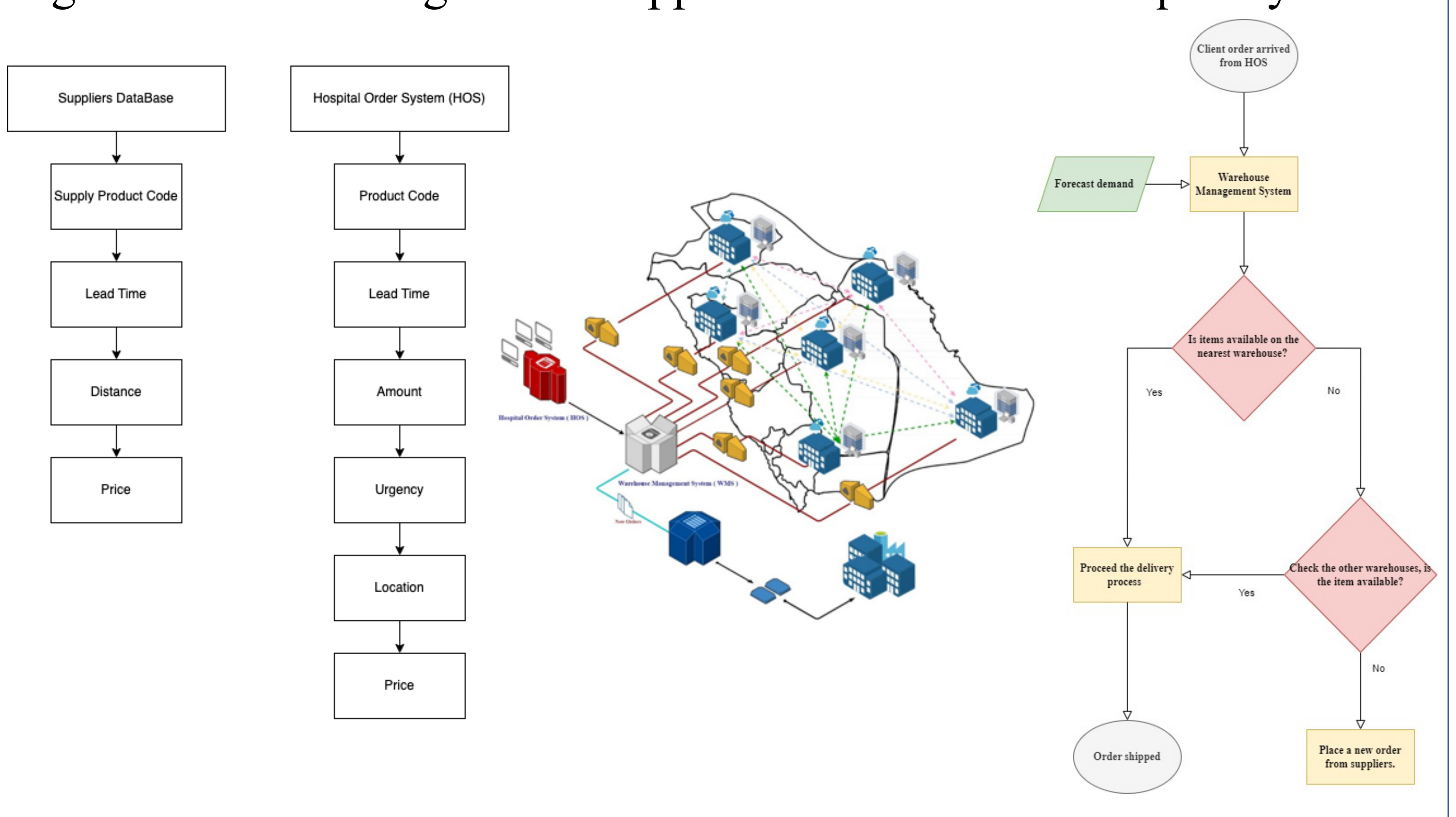
Digital twinning technology is one of industry 4.0 tools. Supply chain digital twinning is to create a virtual replica of the physical supply chain, which can be used to simulate and optimize various scenarios in order to identify opportunities for improvement and reduce risk. Using advanced analytics and machine learning algorithms to model and simulate various scenarios and evaluate their potential impact on the supply chain and identifying opportunities for improvement. In this project the supply chain digital twinning will be implemented on Saudi Arabia's largest corporation in the procurement, logistics, and supply chain management of pharmaceuticals, medical devices, and supplies for governmental hospitals.





Methods and Materials

The proposed solution involves utilizing the digital twin concept to improve NUPCO's operations in a systematic and innovative manner. It includes integrating the hospital Order system and warehouse management system which is built using python, to enable customers to conveniently place orders for medicines. By integrating the two systems and adopting an integrated supply chain, the whole process runs dynamically in real-time, simulating and forecasting inventory levels, connecting the hospitals, and analyzing inventory across all eight warehouses to generate supplier recommendations quickly.

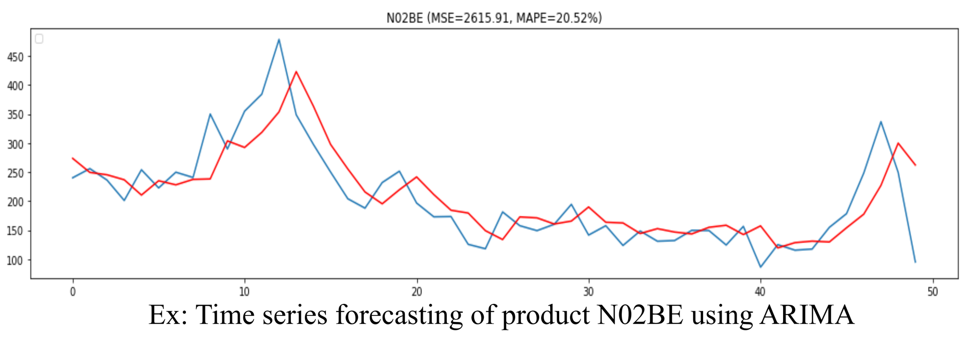


Results and Discussion

Nupco's Digital Twin project aims to optimize its supply chain operations and has significantly decreased overstock, increased automation and integration within the company's supply chain processes and minimize lead time to enhance customer satisfaction.

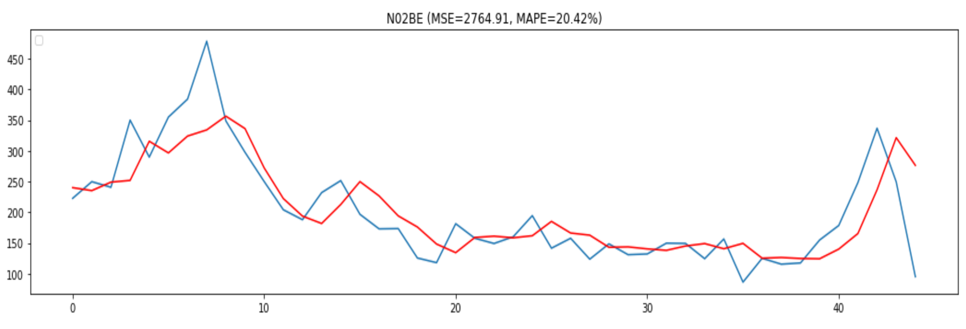
1. Overstocking Solution

Overstocking problem was addressed through several accurate forecasting algorithms and after the implementation of a combination of the 'ARIMA MAPE', 'ARIMA MSE', 'Bidirectional LSTM MSE', and 'Bidirectional LSTM MAPE', the best results were achieved and the lowest mean absolute error percentage was reached.



Ex: Time series forecasting of product N02BE using ARIMA

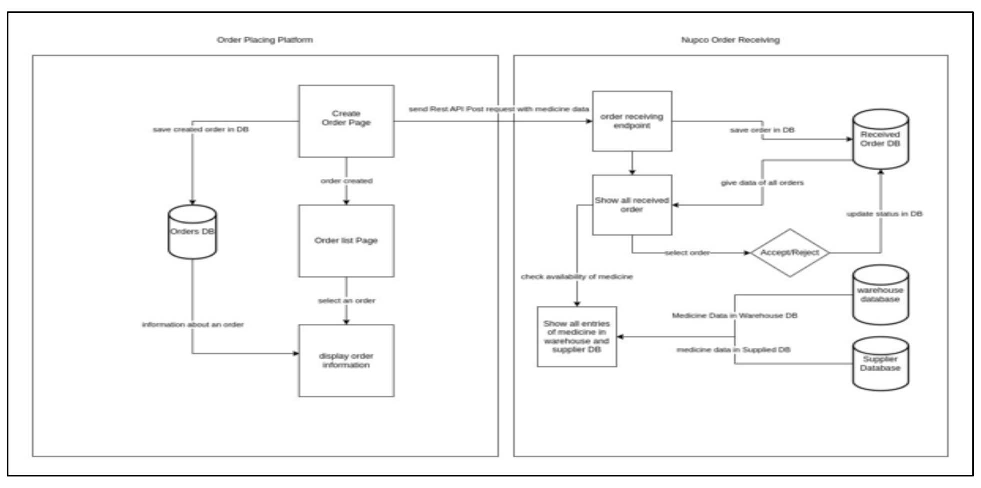
Red: Actual sales
Blue: Predicted sales



Ex: Time series forecasting of product N02BE using Bidirectional LSTM

2. Automation and Integration Solution

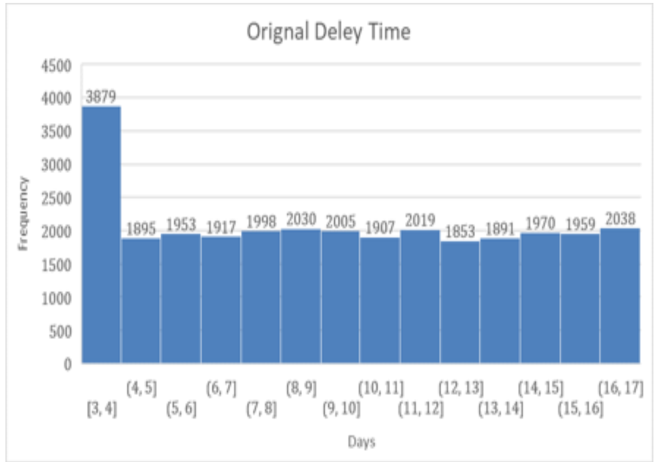
A centralized platform was implemented within Nupco's supply chain, this platform serves as a hub where all supply chain operations are integrated. It encompasses inventory management, order placement, supplier management, and data analysis. The automation of order placement, inventory tracking, and data analysis streamlines operations, allowing the supply chain to operate more seamlessly and making it easier for stakeholders to collaborate effectively. Reducing the time of the supplier picking analysis and the inventory tracking of all warehouses.

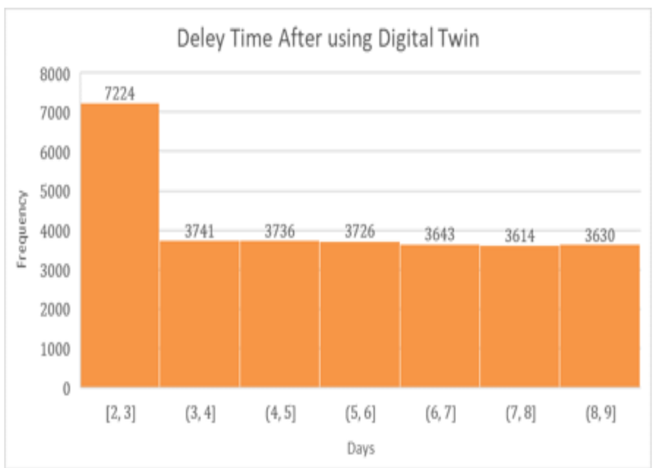


Process Diagram of the centralized platform

3. Excess Delay Solution

A huge improvement has been noticed regarding the acceleration of Nupco's delivery Process where the minimum delay time was 3 days and it decreased to 2 days, while the maximum delay dropped from 17 days to 9 days which represent 47.06% improvement.





Based on the results achieved, the implementation of Nupco's digital twin solution has not only addressed the existing gaps in its supply chain system but has also introduced new capabilities, resulting in significant advantages for the organization.

Key outcomes of the solution include: Centralization and Integration, Real-time Updates, Improved Visibility and Accuracy, Enhanced Reporting and Analytics, Agility and Adaptability, and Scalability.

Conclusions

The implementation of digital supply chain twinning on NUPCO has resulted in significant improvements as delivery time was minimized and customer satisfaction was enhanced by 45.157% on average. Improvements were achieved through integration, visibility, agility, and connectivity by applying the digital twin framework. In addition, accurate forecasting and reduced overstocking were accomplished using real-time data and advanced machine learning algorithms. This has proven to be a valuable solution for NUPCO, enhancing their supply chain capabilities.

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A DECISION-MAKING TOOL FOR OPTIMAL PRODUCTION PLAN

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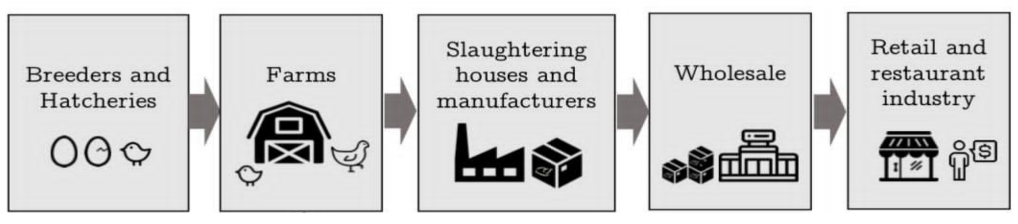
Abstract

One of Saudi Arabia's 2030 vision targets is to increase self-sufficiency in the poultry sector, ARASCO's ENTAJ company increased its production capacity to 60 million birds annually and ranked one of the fastest-growing chicken producers in the Kingdom. Due to high demand, It becomes a must to develop a tool for an optimal decision to meet daily customer demands during the cutting and packaging stage and before distribution arises. The project follows PDCA methodology to comprehend, analyze, and solve the problem, by applying data analytics and operational research method to build an optimization model for making an optimal decision to reduce waste while facilitating and accelerating the decision-making process. The proposed solution shows its effectiveness leading to an increased percentage of demand covering by 5% and a decreased number of downsize by almost 20%.

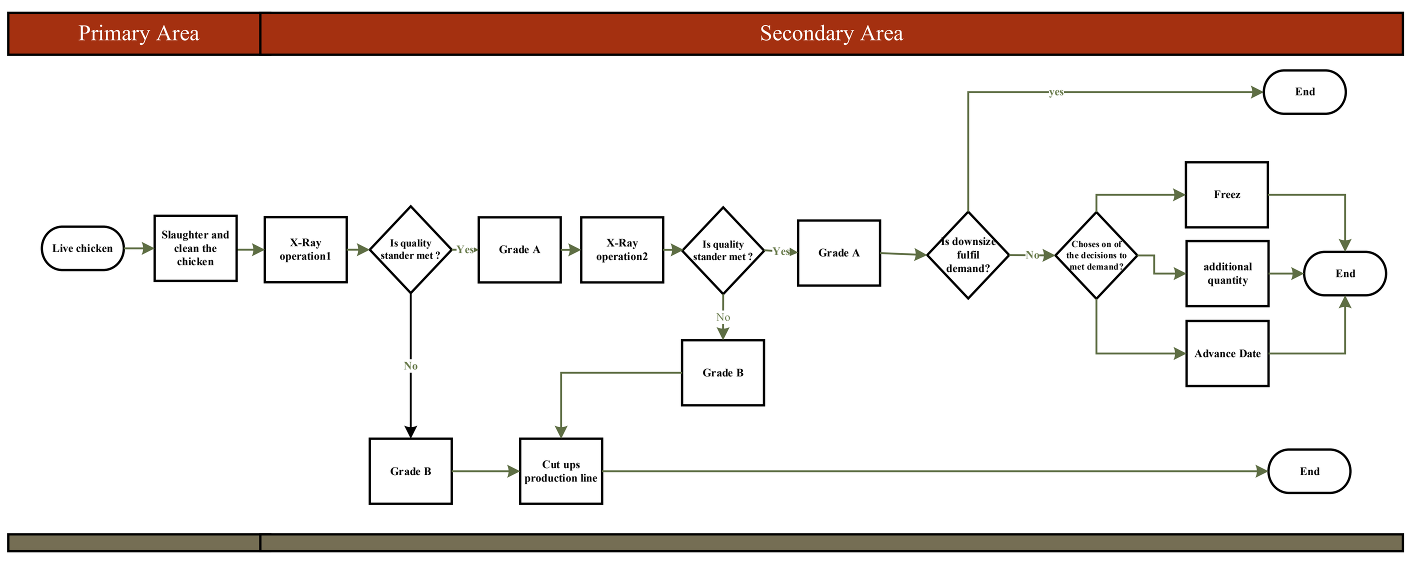
Introduction

The main supply chain process of ARASCO has multiple stages. The project focus is on the third stage which is slaughtering houses and manufacturing that includes the primary and secondary area.



ARASCO supply chain

The primary area includes the slaughter and cleaning operation, while the secondary area includes quality checking where the chicken will be classified as either grade A (produced as whole chicken) or grade B. Consequently, the secondary area has a challenge with supply uncertainty, making it necessary to choose the best course of action among the four decisions and it includes downsize, cut ups, advanced date, and freezing.

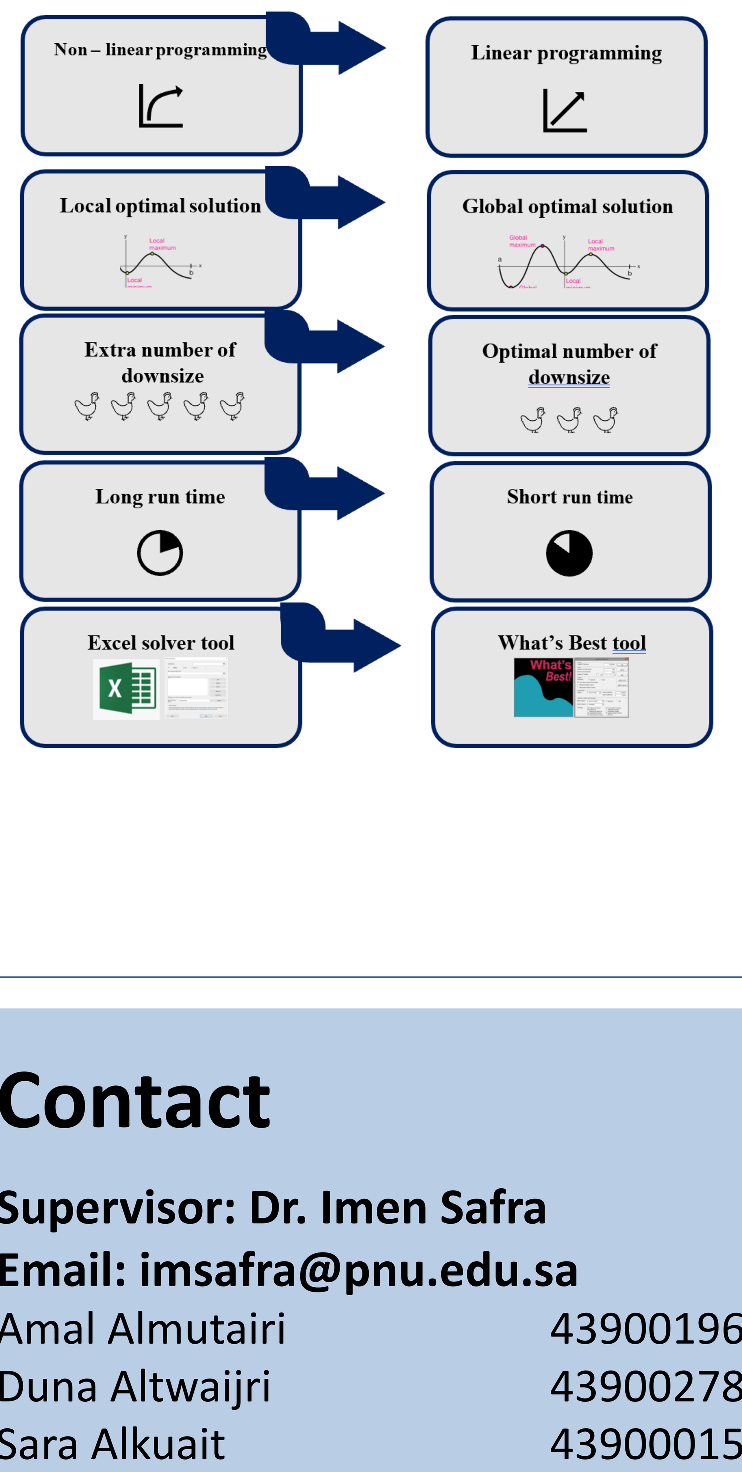


Primary and secondary areas

The project's main emphasis is on downsizing and how to use it to satisfy customers' demands. When a demand for any weight did not match the supply, downsizing took place.

Methods and Materials

The objectives of this project is to satisfy customer demand by maximizing delivered quantity and reaching the optimal number of downsize operation to facilitate decision making process for the labors. Linear programming tools are used to identify the optimal solution. A dashboard is designed to facilitate the production decisions to be established at the operational level. The project follows PDCA methodology to comprehend, analyze, and solve the problem. The problem formulation and the improvement areas of the proposed model are shown below.



Model Formulation

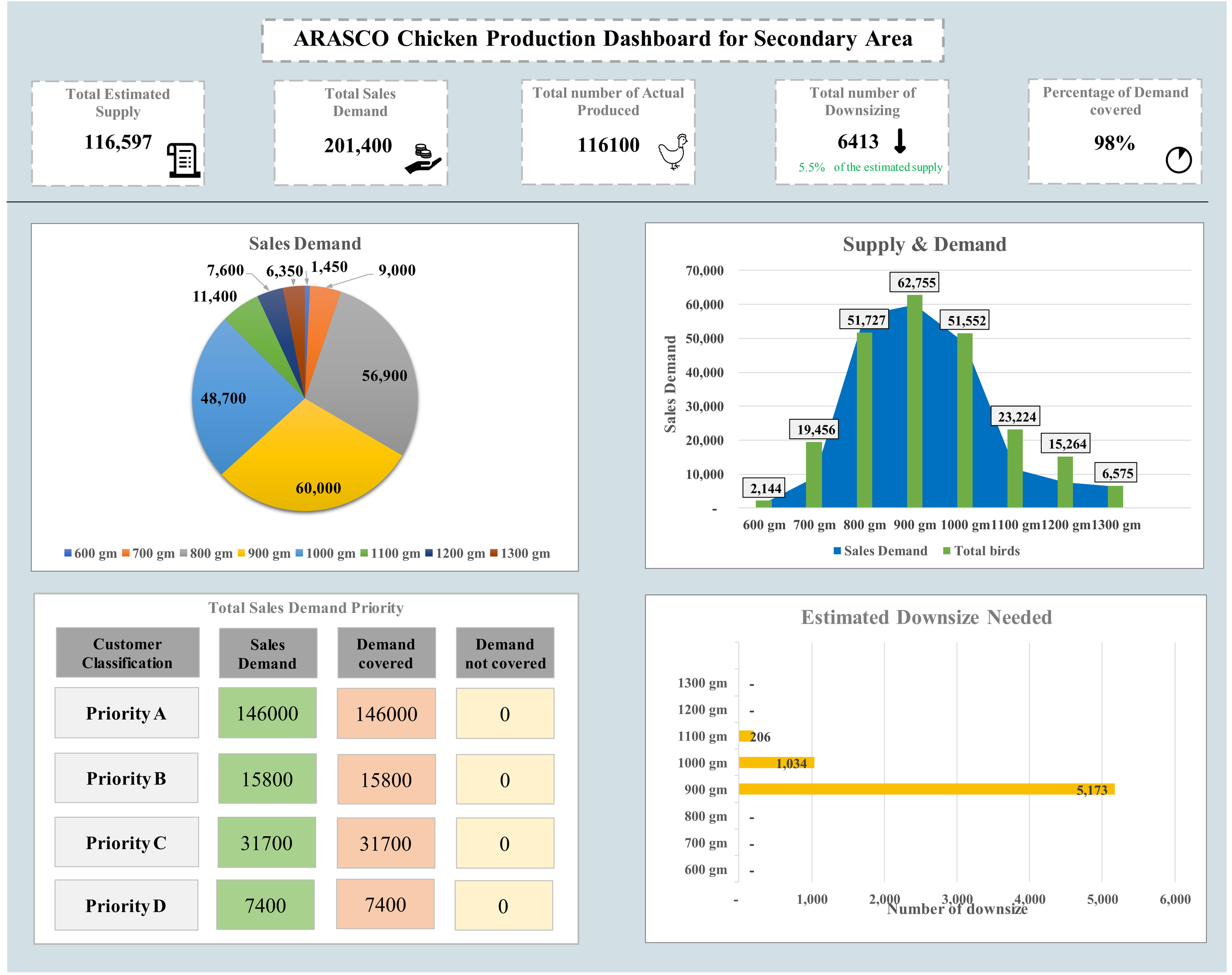
$$Max\ Z = \sum_{i \in I} \sum_{j \in J} w_i * (Es_j - Sd_{ij} + xd_{j+1} - xd_j)$$

Subject to

$$xd_1 = 0 \qquad (1)$$
$$xd_2 \leq 500 \qquad (2)$$
$$xd_3 = 0 \qquad (3)$$
$$xd_j \leq 0.7 * Es_j \qquad (4)$$
$$xd_j \leq abs\left(\sum_{j=1}^{3}(Es_j - Sd_j)\right) \quad j = \{1,..,3\} \qquad (5)$$
$$xd_4 \leq abs(Es_4 - Sd_4) + 0.2 * abs(Es_3 - Sd_3) \qquad (6)$$
$$xd_5 \leq abs(Es_5 - Sd_5) + 0.2 * abs(Es_4 - Sd_4) \qquad (7)$$
$$xd_j \leq abs\left(\sum_{j=6}^{9}(Es_j - Sd_j)\right) \quad j = \{6,..,9\} \qquad (8)$$
$$xd_j \geq 0 \quad \forall\ j \in J \qquad (8)$$

Results

ARASCO has need for a tool that help the laborer understand the output of the model clear way to eliminate the uncertainty within production operation. So, we create Dynamic dashboard to track progress and monitor key performance indicators (KPIs) in real time by connecting them with optimization model. What's Best tool is used to design the dashboard for readable information. Detailed model inputs and outputs are shown in table 1 by using same result of table 2 scenario 2.



Dynamic dashboard

	Model Inputs				Model Outputs	
	SKU	Actual	Estimated Supply " Esi "	Total Demand Priorty	Estimated DS Needed " Xdi "	Total Birds with DS
X1	600	0	2,144	1,450	0	2,144
X2	700	11500	7,956	9,000	0	19,456
X3	800	31022	20,705	56,900	0	56,900
X4	900	32000	30,755	60,000	5173	58,616
X5	1000	23500	28,052	48,700	1034	50,724
X6	1100	5600	17,624	11,400	206	23,018
X7	1200	8089	7,175	7,600	0	15,264
X8	1300	4389	2,186	6,350	0	6,575
X9	1400	0	-	-	0	-

Table 1: Model inputs and outputs

Discussion

Comparing the current situation in ARASCO and the proposed solution alternative, we evaluate the percentage of the covered priority, the number of downsize and the cost of downsize considering 7 scenarios. The obtained results confirm the merits of our solution showing a highest percentage of the priority covered in all scenarios. In some cases, we notice a highest number of downsize operation for our new model, which is justified by a high demand level coverage. The last two scenarios, showing zero downsize quantity, are explained by a supply quantity larger than the sales demand, inducing no need for downsize operation.

	Model Used	Priority covered %	No. of downsize	Cost of downsize
Scenario 1	Current Model	0.71	35603	71206
	New Model	0.78	42859	85718
Scenario 2	Current Model	0.98	29989	59978
	New Model	0.98	6413	12826
Scenario 3	Current Model	0.71	36372	72744
	New Model	0.76	34199	68398
Scenario 4	Current Model	0.69	12717	25434
	New Model	0.87	12412	24824
Scenario 5	Current Model	0.71	37703	75406
	New Model	0.73	37790	75580
Scenario 6	Current Model	0.98	39551	79102
	New Model	0.98	0	0
Scenario 7	Current Model	0.98	12472	24944
	New Model	0.98	0	0

Table 2: Sensitivity analysis

Conclusions

Poultry industry has an increasing, urgent and unforeseen demand, so there is an imminent need to develop an effective production plan with an optimal solution that will help ARASCO company reducing their waste and meeting the supply with demand. In this project we followed PDCA approach. The proposed decision-making tool will improve the accuracy of estimated downsize quantity by using integer linear programming. Moreover, we develop a dashboard to keep track with production progress and to analyze results. Our proposed solution shows its effectiveness leading to an increased percentage of improvement for demand covering by 5% and a decreased number of downsize by 20% ± 5% in different scenarios.

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Designed Solution For an airline company: Crew Pairing Optimization

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Abstract

Flight scheduling and crewing decisions are paramount for airlines, given the intricate nature of crew pairing and regulatory compliance. Optimizing effectiveness and reducing costs in this area is highly sought after. Airline crew pairing serves as a captivating application for Operations Research. During this project, a solution has been devised to optimize crew pairings for maximum efficiency while considering constraints like crew lifestyle, satisfaction, flight duration, cost, availability, and regulations. The project encompasses three main phases: defining objectives, analyzing the current situation, and developing a conceptual solution. The objective is to strike a balance between crew utilization and constraints, resulting in significant cost savings while maintaining safety and service standards. Applying comparative techniques offers promising opportunities for improving effectiveness and cost reduction in flight scheduling and crewing decisions. The Flynas project focuses on analyzing and optimizing crew pairings, considering various constraints, and adhering to regulations. By leveraging these techniques, airlines can enhance operational efficiency, reduce expenses, and ensure compliance.
Keywords: Optimization, Crew Pairing, Airline Scheduling Problems, Two and Three Sectors Pairing

Introduction

Flynas, a Saudi low-cost airline, plays a major role in the global economy and a leading low-cost airline based in Saudi Arabia. Flynas operates 1500 weekly flights to 70 domestic and international destinations with 38 aircraft. The airline planning process involves several key steps, as illustrated in the accompanying figure 1.

Setup The Timetable → Fleet Assignment → Crew Pairing → Crew Assignment

Figure 1: The Resource Planning Process in Airline

Crew pairing is a critical aspect of airline operations, involving the scheduling and assignment of flight crews to specific sequences of flights, known as duties. These duties consist of one or more legs, interspersed with designated rest periods. Optimizing crew pairing is crucial because airlines' second-largest expense is crew operations. Crew pairing generation and optimization solve crew scheduling. To reduce pairings and ensure compliance, this project will use a three-sector pairing method. Flynas wants to cut costs and maximize crew use. The project aims to reduce Flynas' costs and optimize crew utilization by carefully considering regulations and pairing methods. This will improve the airline's efficiency and finances performance .

Methods and Materials

The methodology employed in this project entails the collection, comprehension, and analysis of data to facilitate informed decision-making. Various decision-making tools are utilized to evaluate and determine the superior alternative among the options under consideration. By leveraging these tools, the project aims to make sound, evidence-based choices that optimize outcomes. Once the problem is defined, the initial stage entails the collection of relevant data. Subsequently, the data is comprehended and assessed for its usefulness, ensuring that it holds value for the project. Decision-making tools are then employed to evaluate different alternatives based on multiple criteria (Fig 2). The use case diagram (Fig 3) is used to represent the dynamic behavior of the AIMS Software used by Flynas and how different actors interact with the system

Figure 3: AIMS Use Case Diagram

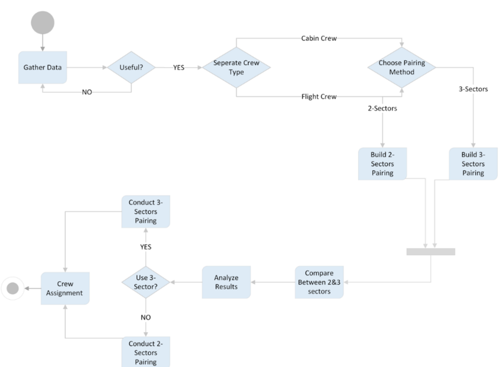


Figure 2: Process Flow Chart

To streamline the crew pairing process and enhance overall airline performance while minimizing costs, Flynas relies on AIMS airline software. AIMS serves as a core system, encompassing vital functionalities such as pairing constructions, automated legality checks for manual crew assignment, and basic administration of leave and training and displayed in the form Gantt chart as shows in figure 4 and 5.

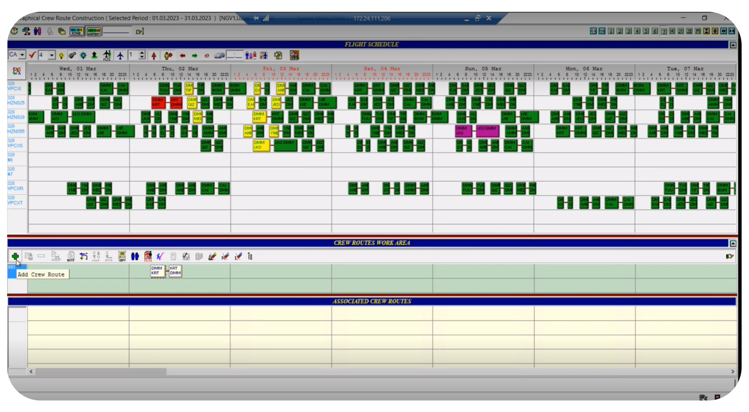


Figure 4: AIMS software interface (1)

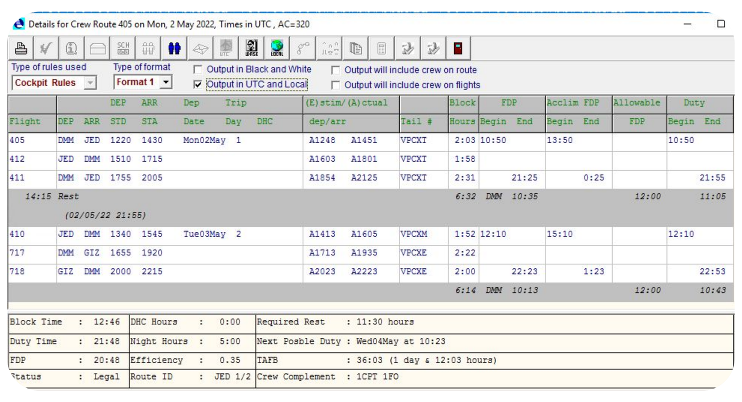


Figure 5: AIMS software interface (2)

Results and Discussion

Statistics in figure 6 show that the ratio of pairings to flights has decreased by 7% in the month of three sectors' method (2022). That would increase crew utilization and reduce operational costs by assigning them to more flights.

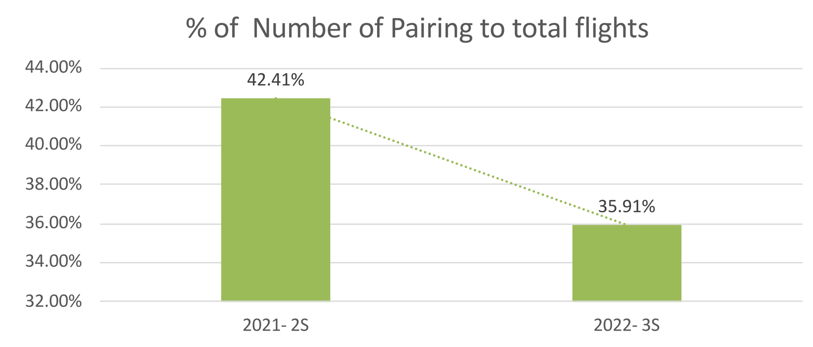
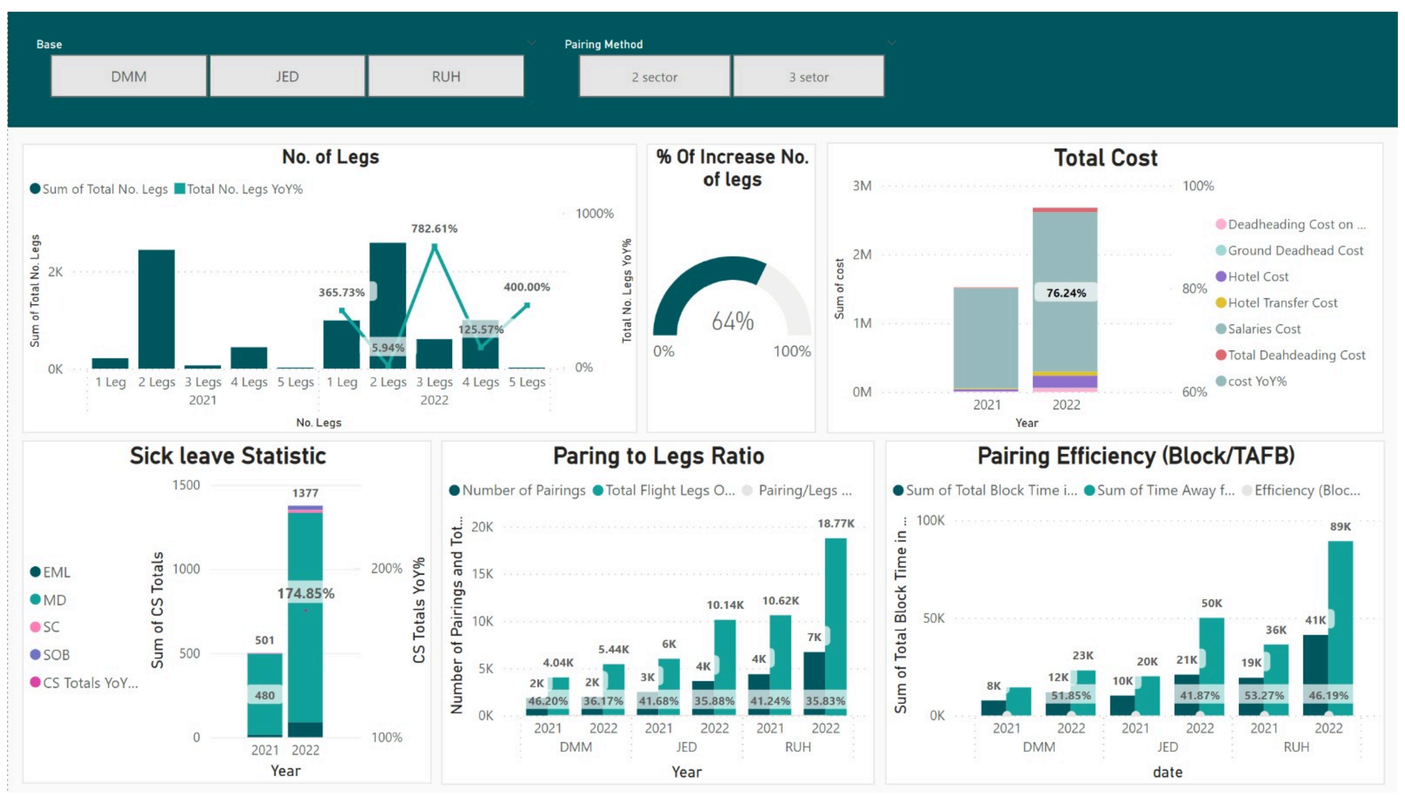


Figure 6: Number of Pairing to Total Flights

The proposed solution entails adopting the three sectors method for crew pairings, complying with GACA regulations and Flynas's internal policies. This approach involves creating a sequence of connectable flight legs within the same fleet, originating from one base and concluding at another destination, necessitating the crew to be away from their residence. Implementing this solution reduces crew pairing complexities, enhances crew flight hours while adhering to legal constraints. Data analysis, supported by decision-making tools such as the Dashboard and KPIs, confirms the effectiveness and benefits of the three sectors method.



SWOT analysis highlights strengths in optimizing crew schedules, weaknesses in crew fatigue, and opportunities in new technologies and regulations. Mitigating risks like flight disruptions and competition is crucial. Implementing the cost-effective solution may face cultural obstacles. Criteria including number of pairings, crew satisfaction, cost-effectiveness, and crew utilization are used for further analysis using AHP and Weighted Scoring Method to determine the most efficient pairing method.

Conclusions

The project aims to minimize crew pairing days during scheduling at Flynas Airlines, reducing operating costs. Pairings are based on three sectors, adhering to regulations and internal policies. Results demonstrate improved crew utilization. However, limitations include crew lifestyle, culture, and Flynas' low-cost strategy. Future recommendations involve attracting part-time crew members and introducing the concept of three sectors early in their career for practical implementation.

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DEVELOPING A METHODOLOGY FOR WASTE MANAGEMENT AT PNU

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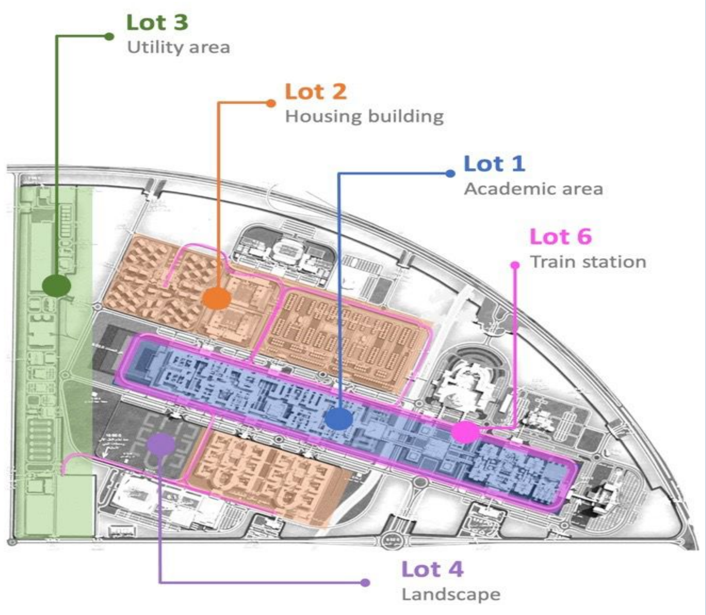
Abstract

Waste handling is a concern due to the continuous increase of waste production; proper waste management (WM) is a must to reduce the environmental consequences and regulate expenses. Princess Nourah University (PNU) is one of the largest universities in the Kingdom of Saudi Arabia with massive amounts of waste produced. Therefore, it is crucial to evaluate the current situation of this educational institution in terms of whether there are any issues with improper waste handling, storage, and transportation within the university facilities. Resource reuse or recycling is an efficient way for contributing into the transformation from a linear economy to a circular economy to be aligned with the 2030 vision that focuses on enhancing and protecting the environment and economical sustainability. The project aims to develop a WM methodology at PNU that uses an integrated system to collect data that can assist decision-makers in creating sustainability strategies, which can be used to support the university's sustainability efforts. Additionally, this project aims to contribute to the sustainability movement at PNU and serve as a starting point for future research concerned with developing the WM system to preserve the environment.

Introduction

Princess Nourah University is one of the largest universities in the Kingdom of Saudi Arabia with over 600 facilities and an area of 8 million square meters, these facilities generate massive amounts of waste approximately 50 tons/day. To achieve compatibility with vision 2030 .Waste is managed by responsible waste-handling service contractors that are responsible for different areas (5Lots).

In this context, the present project aimed to propose a clear and controlled methodology that will result in a better understanding of WM, as well as a clear vision of the governance methodology that serves the current and future situation while operating within a controlled software system that achieves a sustainable university environment.

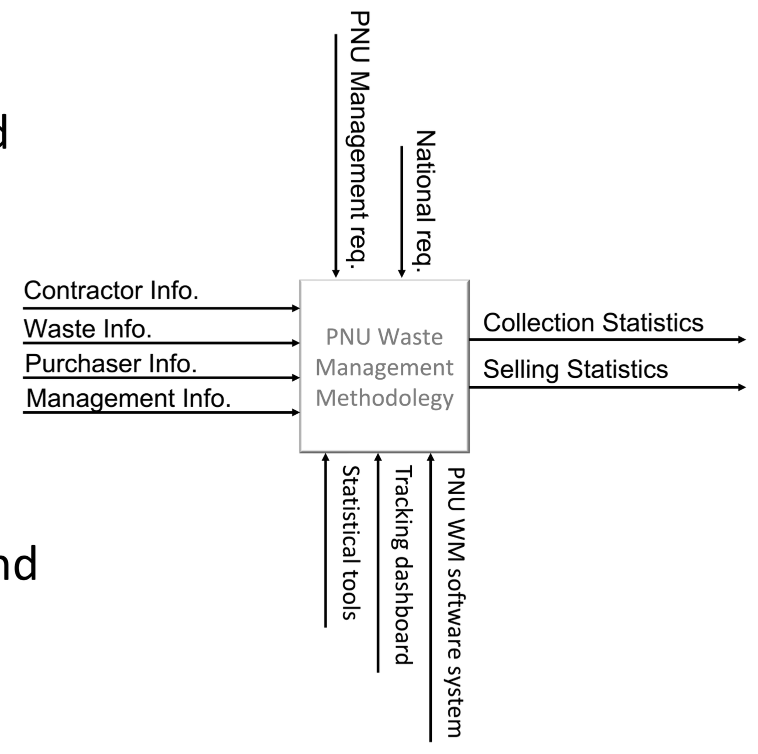


Methods and Materials

The proposed project aims to develop a methodology for WM that increases the ability of the institution to monitor and control waste disposal operations and seize investment opportunities that can be advantageous. An investigation of the current state was accomplished through site visits, and interviews conducted with the university contractors to build a solid understanding of the existing situation.

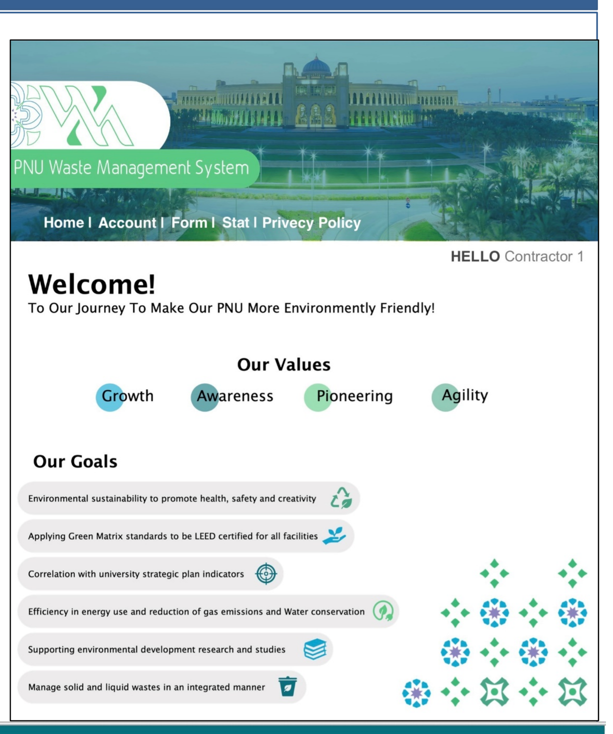
After analyzing the gaps in the current system, a methodology was developed that included a cloud-based system, in which different techniques were developed to have a fully managed system offering authorization level access, dynamic statistics and support building a WM database using:

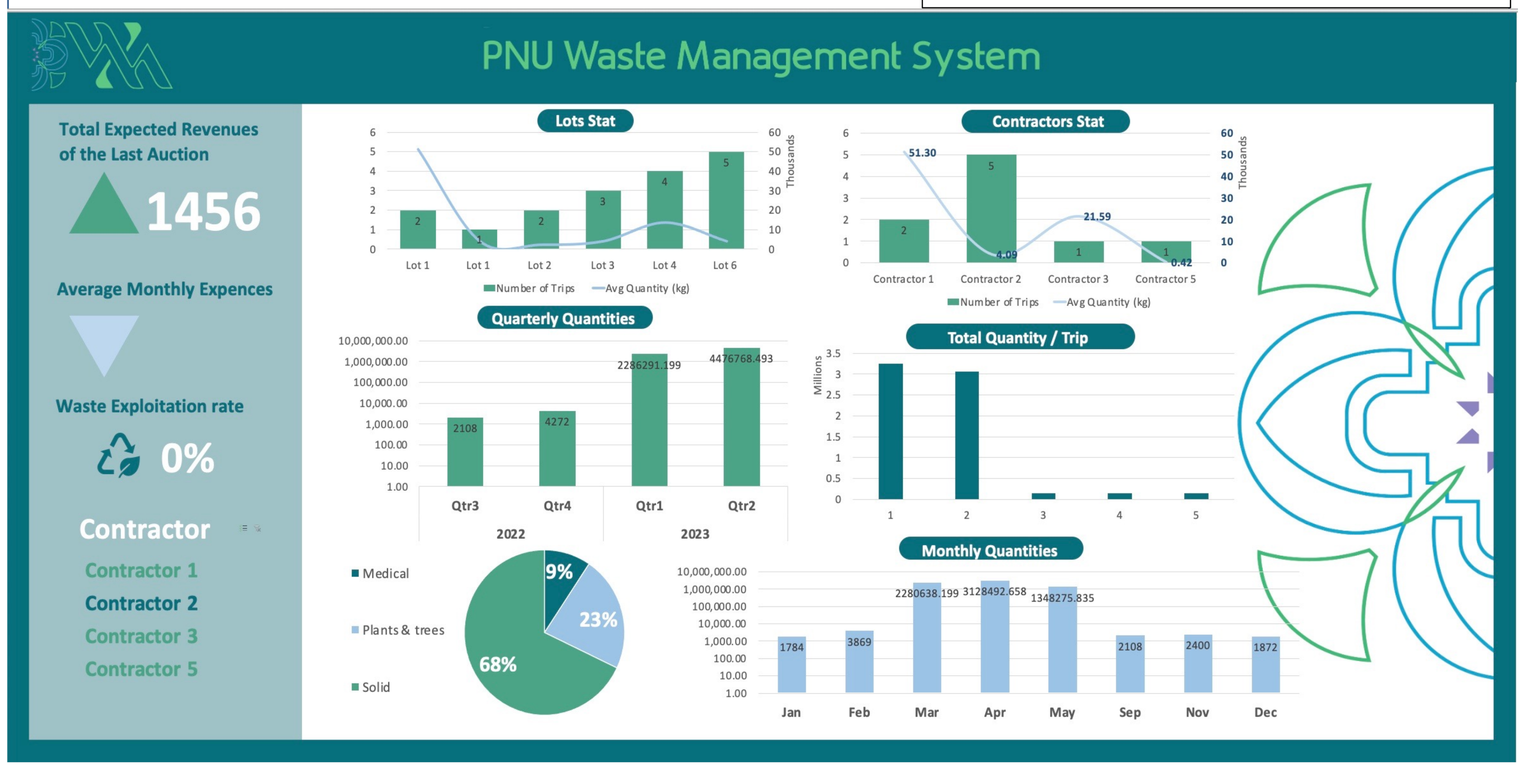
- Microsoft Access to create the software system using VBA and SQL languages.
- Microsoft Excel for data visualization in the dashboard.
- Minitab to analyze trends, to develop a forecasting model and to examine ARIMA.



Results

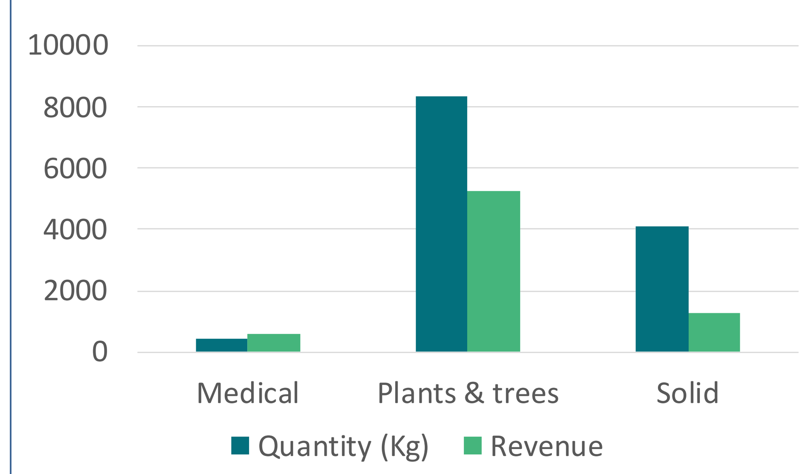
PNU WM software system assists Decision makers track the waste process through close involvement with the university contractors. The software system also facilitates data collection and analysis to detect opportunities of reducing WM costs and estimating the potential gain of introducing recycling and composting.

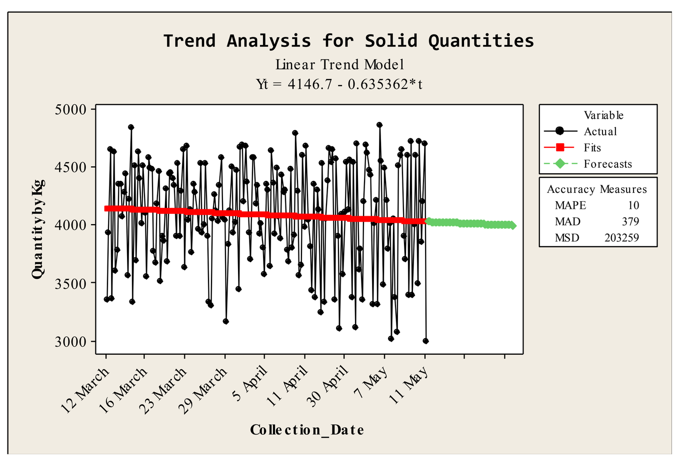


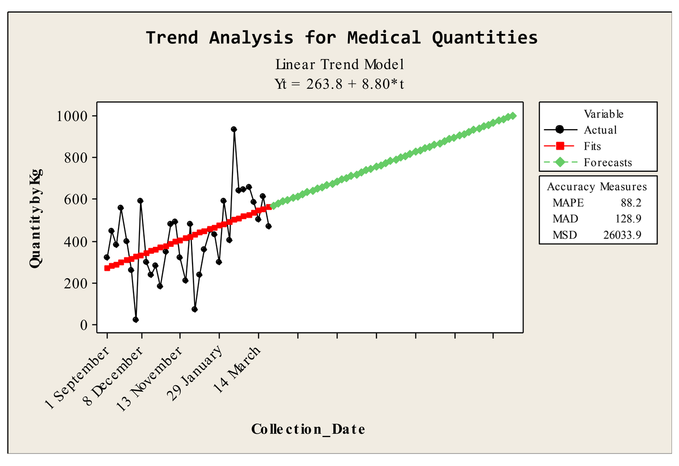


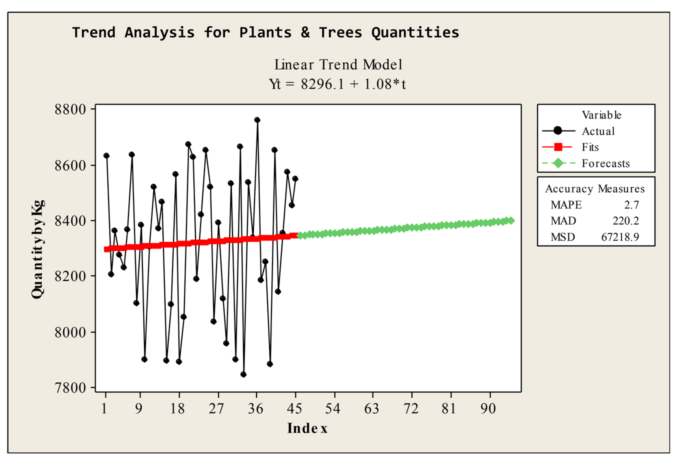
Discussion

Developing a waste management software system led to a great extent of improvement to the data collection process within PNU. When contractors substitute the current operational system of collecting waste with the suggested solution that deal with the waste collected separately, it will be possible for the contractors and the university to calculate the expected revenue.









By using trend analysis to forecast (Solid, Medical and plants & trees) it shows that the quantities of medical and trees classifications are increasing while solid is constant over time.

In the ideal situation all the current quantities assumed to be sold and the expected revenue per semester will be 462,173 SAR

The revenue will increase by 9% for the next semester, once all quantities generated within PNU were sold.

Conclusions

PNU large infrastructure is a rich environment for the study of WM because it works to limit the effect of waste on the environment, health, and economics. A well-developed waste management methodology will aid in the efficient and effective reduction of waste generation at source and increase the reuse of resources. The current situation was studied and compared to international practices to discover gaps. A system was developed to cover these gaps. It is recommended to develop a segregation process and its important to launch awareness campaigns about the importance of recycling waste and offering instruction on how to properly dispose different types waste, and finally making sure that the necessary data is entered on a regular basis in the software system.

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Smart Distribution of Flights to Maximize Gates Efficiency and Minimize the Accumulated Time of Delayed Flight.

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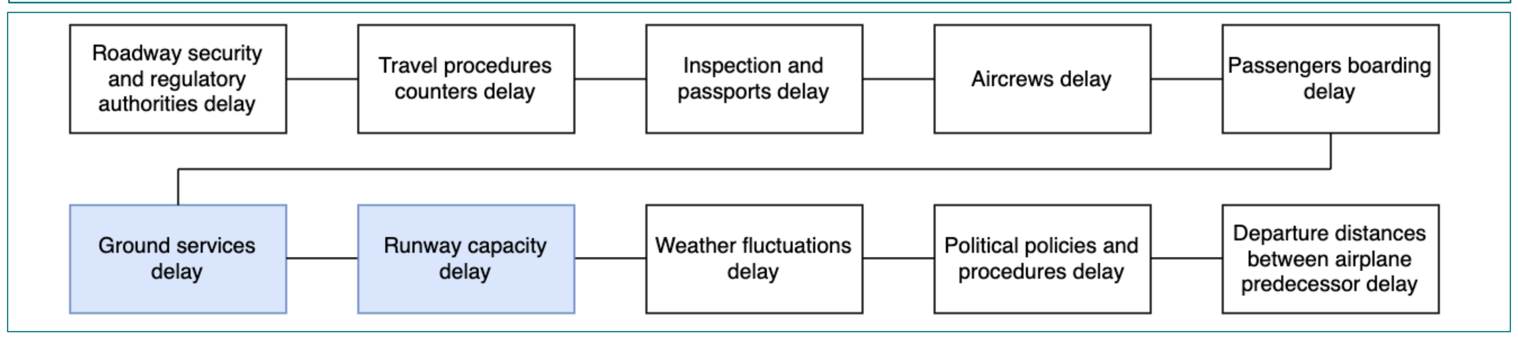
Abstract

Aviation industry is enduring from the flights delay which cost billions to both business providers and consumers per year, in addition to its noxious impact on environment and bad customer services experience. This project has investigated the time performance influencers of all stakeholders' practices and its delays causes, to results a focus on the gate capacity delay which proved to be inefficient in King Khalid International Airport. Hence, the accumulated delayed flights will be minimized by applying machine learning and deep learning tools to forecast delays to build a high-accuracy optimization model to reschedule the affected flight and test the validity by applying the Arena simulation software, and thus the efficiency of gates will increase by increasing its utilization percentage. This will lead to reducing costs resulting from flight delays, preserving the environment from carbon dioxide emissions, and increasing customer satisfaction. Taking in advance international safety standards in the aviation industry, and General Authority of Civil Aviation (GACA) laws and regulation. Although the delay cannot be entirely avoided, it can be reduced by consuming time wisely.

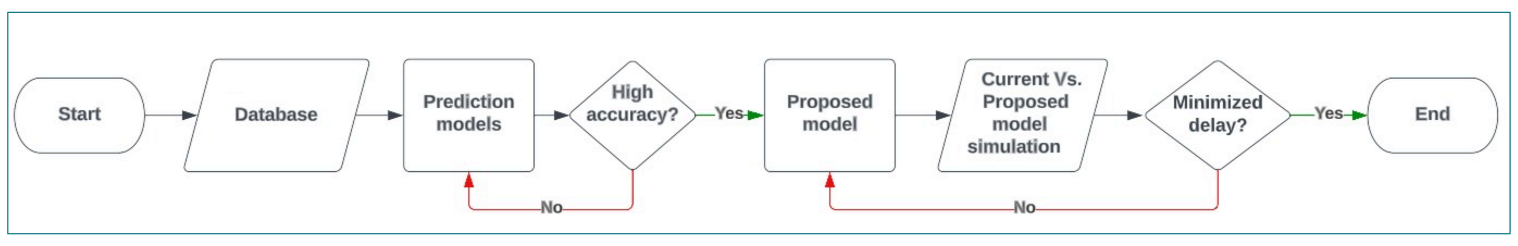
Introduction

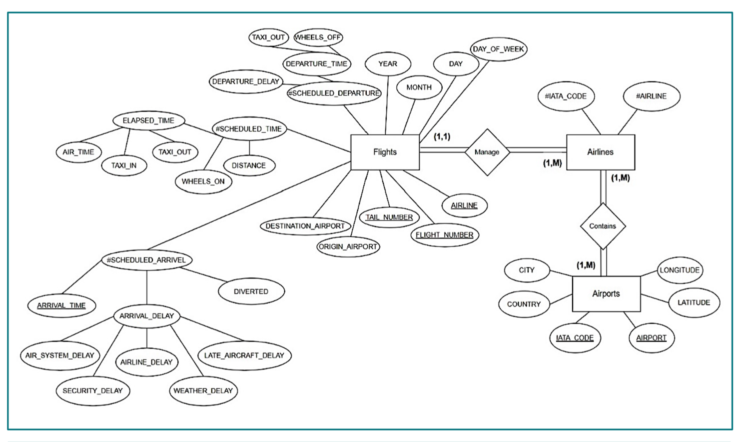
The variation between demand and capacity, along with the minimal capacity utilization of the gates, results a massive consequence in flight delays, as in the United States, the direct aircraft operation cost to be total of $80.52 per flight per minute.
Also, the utilization percentage of the gate of King Khalid Airport is no more than 50%. With the intention of controlling cost, a model will be built by minimizing the accumulated delayed flights to maximize the efficiency of gates and increase its utilization percentage. Emphasizing the ground services and runway capacity delays.



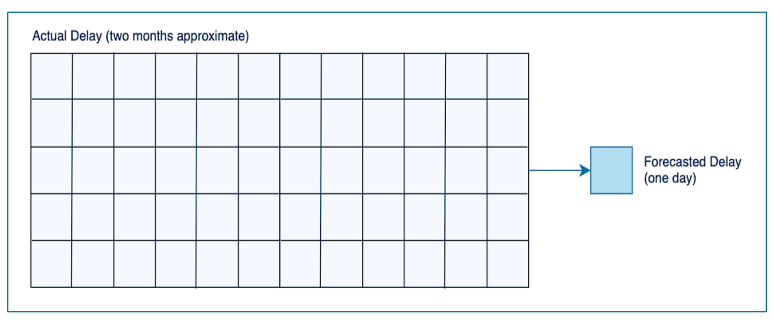
Methods and Design

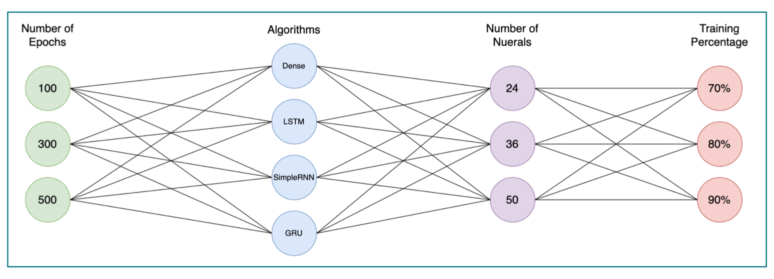
The model will test the U.S. database accompanying with feasible details of GACA laws and regulations, in addition to its planning constrains with Riyadh Airports and its operational constraints with Saudi Ground Services Company (SGS). In the aim of providing better planning and operation system to the stakeholders in aviation industry, and to maximize the efficiency.
Flight delays data is complex, subtle with different variation and must be analyzed using the most efficient method of analysis of variance (ANOVA) to determine the verity of treatments groups affecting flight delays. The solution flow will start by testing the accuracy of several prediction models. After that, the optimization will be used on the model with the highest accuracy. Finally, simulations will be run to test the validity and gate utilization.
Due to the non-linear nature of the flights delay data, and its complexity, machine learning algorithms has proven to be inefficient, unlike the deep learning's artificial neural network (ANN), which proven to provide lower error metrics.

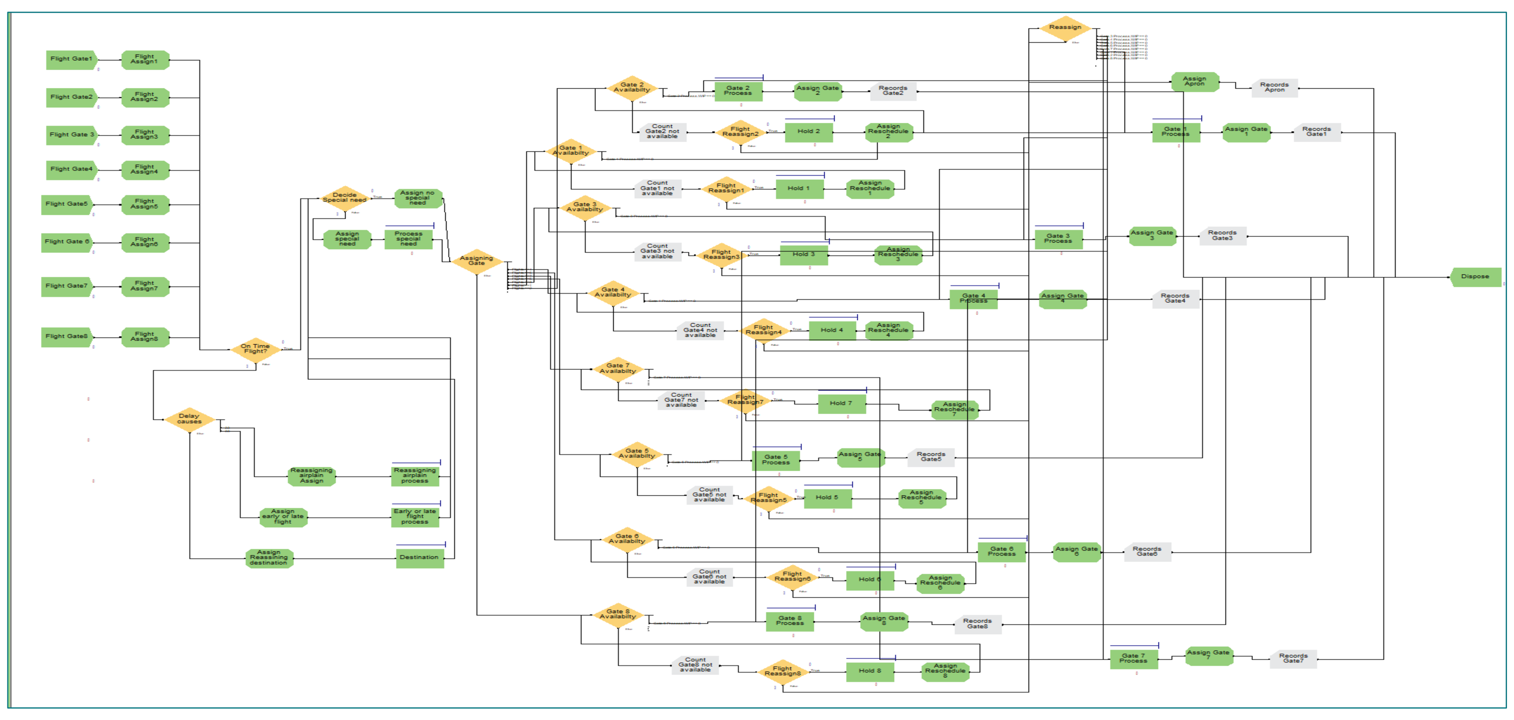




Factor	Values	No. Levels
Day	Mon, Tue, Wed, Thu, Fri, Sat, Sun	7
Month	Jan, Feb, Mar	3
Arrival Period	1, 2, 3, 4	4

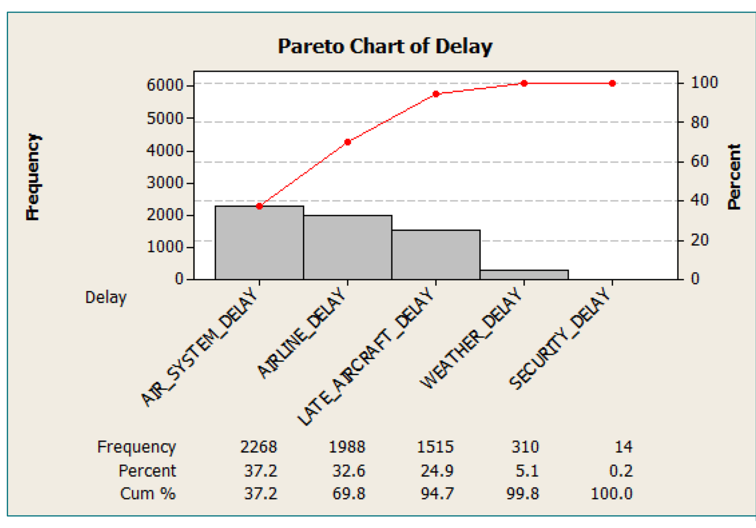


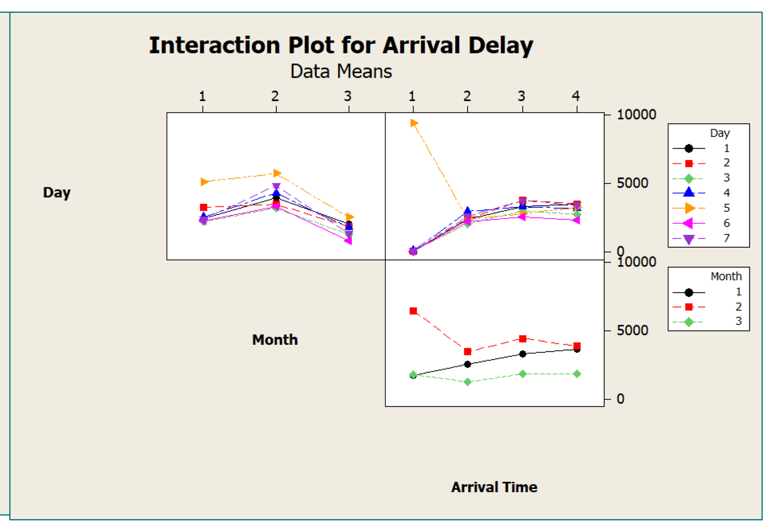


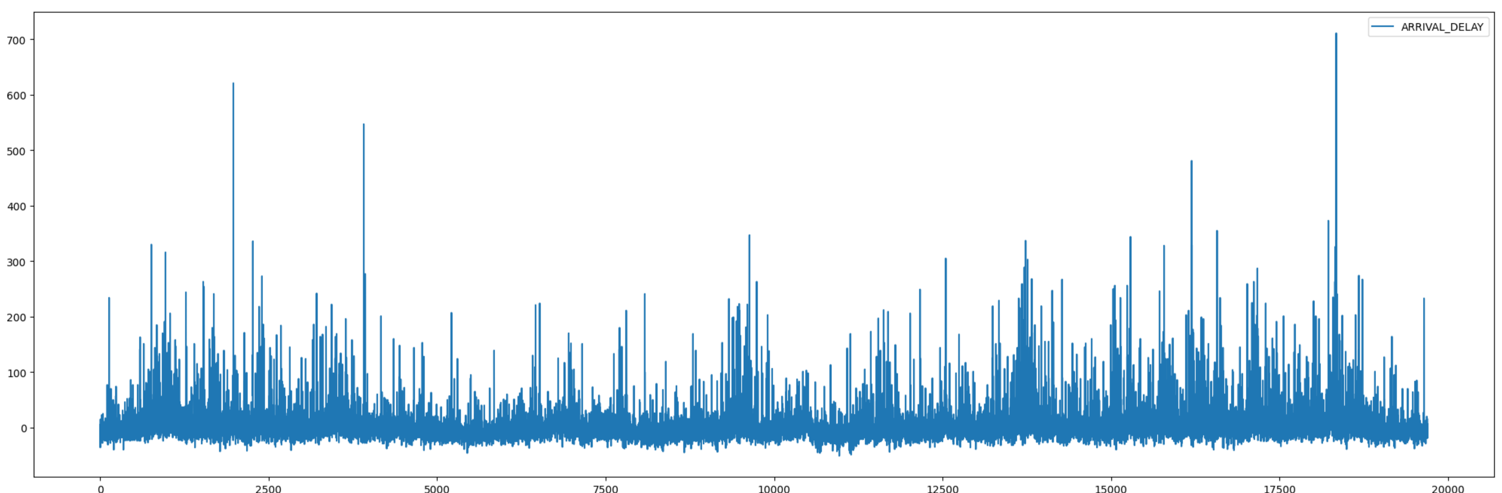


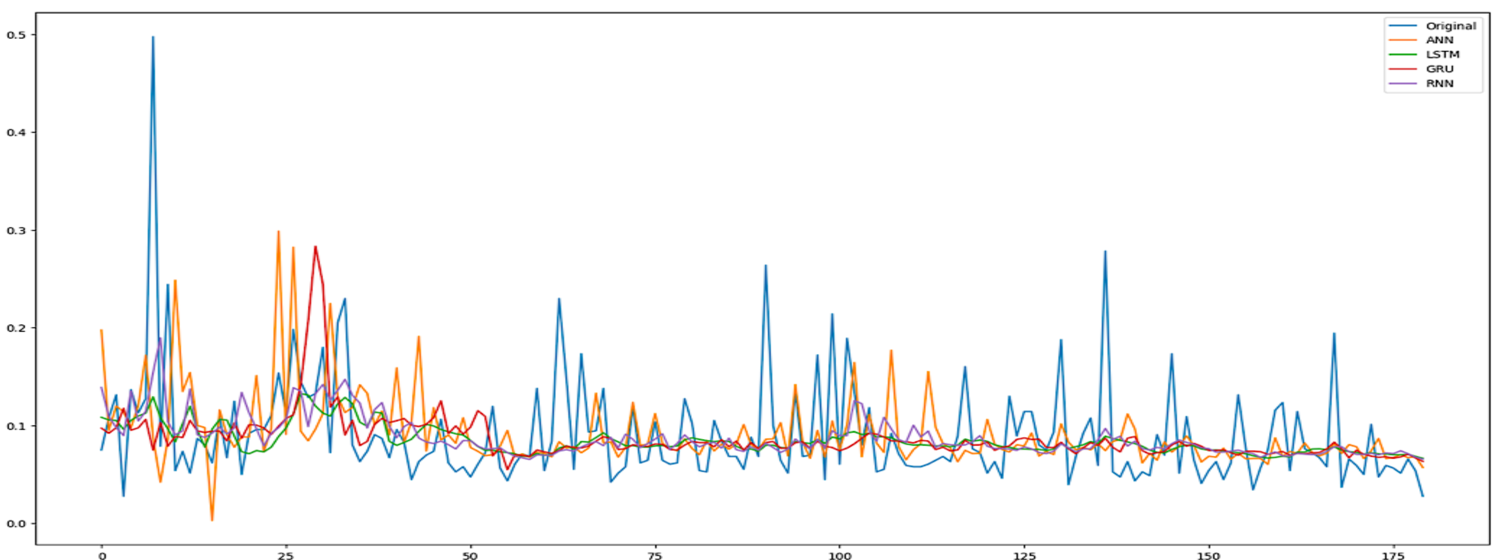
Results and Analysis

The proposed approach will begin by implementing the factorial ANOVA with its interactions to gain a general insight into the behavior of the data. Both Day and Month are significantly affecting the delays. While the Arrival Period has no significant impact in its alone, it affects the delay when interacting with the Day factor. Results proves the validation of the time series factor in the data; therefore, the forecasting models are more appropriate using in predicting the future flights delay.
Best option determined using deep learning to be: Adam optimizer, 100 epochs, long short-term memory (LSTM), 50 neutrals, and 90% training percentage
Also, according to the statistics, air system delays occur most frequently, while security delays occurs least frequently.



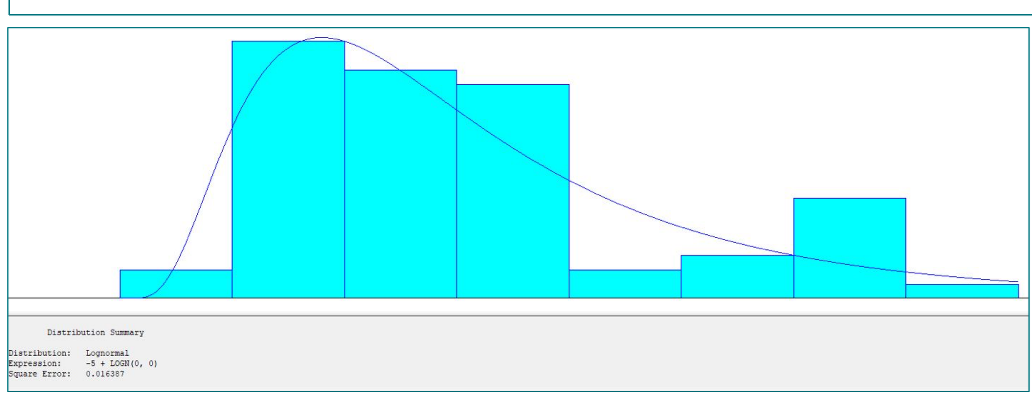






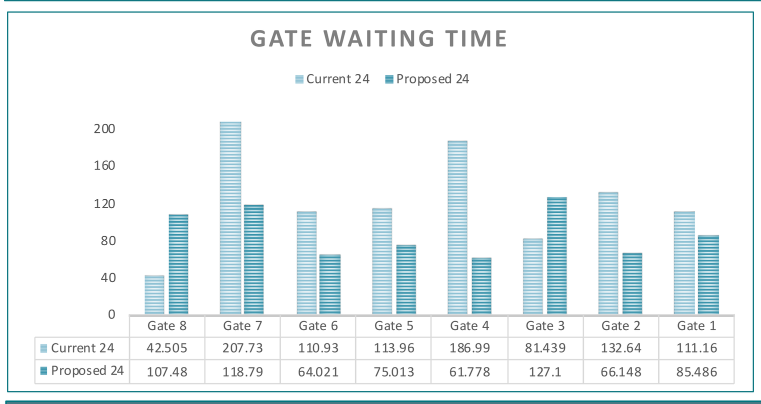
Evaluation and Validation

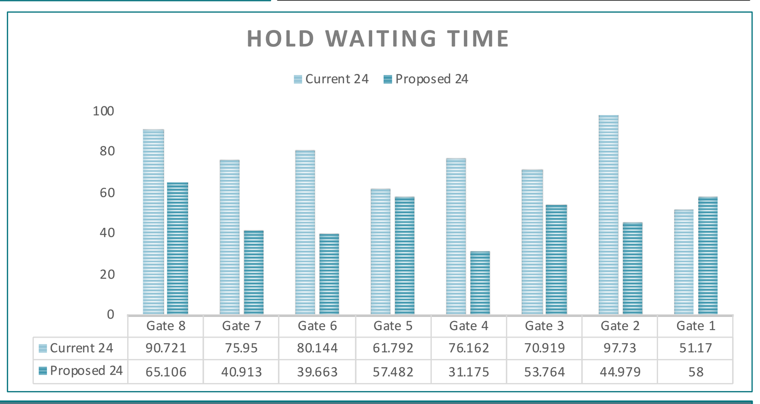
Both lead time and cycle time have been minimized for the proposed solution, which prove that the objective of the model has been met. Waiting time investigations indicate that the proposed model is more efficient since most of the waiting time gates has been minimized in both gate and hold processes. The number of rescheduling attempts of the flights in the proposed model have proven to be increased, due to the proactive advantage of the forecasted delayed data, which indicates the efficiency of the model to make a faster decision making, since the delay has been minimized.
The efficiency of the model has been tested demonstrating maximize the utilization percentage of the operational system. The utilization percentage of the proposed model has been minimized; this indicate that the capacity of the flights in the proposed model can accommodates approximately double capacity of flights per day with same resources. Which validate the optimization aspect of the proposed model.



Values	Current 24	Proposed 24	Change Rate
Lead Time	83.181	68.458	-0.177
Cycle Time	969.840	857.750	-0.116

Utilization	Current 24	Proposed 24	Proposed 48
Gate 8	24.80%	24.92%	31.50%
Gate 7	29.60%	25.10%	31.70%
Gate 6	31.50%	24.89%	31.55%
Gate 5	33.30%	25.01%	31.64%
Gate 4	35.20%	24.88%	31.65%
Gate 3	36.70%	25.00%	31.70%
Gate 2	26.70%	25.07%	31.69%
Gate 1	27.50%	25.08%	31.71%
Average	30.70%	24.99%	31.64%





Conclusions

The proposed solution in this project proves its efficiency in meeting the intended objectives of minimizing the flights delay by 17.7% and optimizing the resources capacity with the approximate utilization percentage. This will lead to reducing costs resulting from flight delays, protecting the environment from carbon dioxide emissions, and increasing customer satisfaction.

Contact

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