Waste Collection Service Analysis in a Smart City. A study case in Torreon, Coahuila, Mexico

Análisis del Servicio de Recolección de Residuos en una ciudad inteligente. Un Caso de Estudio en Torreón, Coahuila, México

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KEYWORDS:

Data mining, Vehicle routing problem, Waste collection

ABSTRACT

Effective waste management is essential for maintaining a clean and sustainable urban environment. This paper addresses the waste collection challenges in Torreón, Coahuila, Mexico, by integrating data mining techniques with the vehicle routing problem (VRP). The goal is to optimize waste collection routes and schedules to minimize costs, reduce fuel consumption, and enhance operational efficiency. The study leverages historical waste collection data, demographic information, and geographic data to comprehensively understand waste generation patterns, population density, and infrastructure layout. The data mining process involves exploratory analysis, clustering, and classification techniques to identify critical variables and patterns that influence waste generation and collection. This information is used to design efficient collection routes, considering factors such as distance, capacity constraints, traffic patterns, and time windows. The VRP model is then applied to allocate waste collection vehicles optimally, ensuring that each route is serviced within the designated timeframe. The model aims to minimize the number of vehicles used, optimize capacity utilization, and reduce travel distances. Additionally, real-time data on vehicle status, traffic conditions, and waste generation rates are integrated to adjust routes and schedules to improve operational efficiency dynamically. This approach provides waste management authorities in Torreón with valuable insights and tools to enhance waste collection operations. By leveraging data mining and VRP techniques, the study aims to improve waste management practices, reduce environmental impact, and promote a cleaner, healthier environment for residents of Torreón, Coahuila, Mexico.

PALABRAS CLAVE:

Minería de datos, Problema de ruteo de vehículos, recolección de residuos

RESUMEN

El manejo de residuos efectivo es esencial para mantener un ambiente urbano limpio y sostenible. Este trabajo aborda los desafíos de la recolección de residuos en Torreón, Coahuila, México, mediante la integración de técnicas de minería de datos con el problema de ruteo de vehículos (VRP). El objetivo es optimizar las rutas y los horarios de recolección de residuos para minimizar los costos, reducir el consumo de combustible y mejorar la eficiencia operativa. El estudio aprovecha datos históricos de recolección de residuos, información demográfica y datos geográficos para comprender integralmente los patrones de generación de residuos, la densidad de población y el diseño de la infraestructura. El proceso de minería de datos implica técnicas de análisis exploratorio, agrupamiento y clasificación para identificar variables y patrones críticos que influyen en la generación y recolección de residuos. Esta información se utiliza para diseñar rutas de recolección eficientes, considerando factores como la distancia, las limitaciones de capacidad, los patrones de tráfico y las ventanas de tiempo. El modelo VRP se aplica entonces para asignar vehículos de recolección de residuos de forma óptima, garantizando que cada ruta reciba servicio dentro del plazo designado. El modelo tiene como objetivo minimizar la cantidad de vehículos utilizados, optimizar la utilización de la capacidad y reducir las distancias de viaje. Además, se integran datos en tiempo real sobre el estado del vehículo, las condiciones del tráfico y las tasas de generación de residuos para ajustar rutas y horarios para mejorar la eficiencia operativa de forma

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dinámica. Este enfoque proporciona a las autoridades de gestión de residuos de Torreón información y herramientas valiosas para mejorar las operaciones de recolección de residuos. Al aprovechar las técnicas de minería de datos y VRP, el estudio tiene como objetivo mejorar las prácticas de gestión de residuos, reducir el impacto ambiental y promover un medio ambiente más limpio y saludable para los residentes de Torreón, Coahuila, México.

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1. INTRODUCTION

Efficient waste collection is critical to urban management to ensure a clean and sustainable environment. In Torreon, Coahuila, Mexico, optimizing waste collection routes and schedules is paramount to minimize costs, reduce fuel consumption, and enhance operational efficiency [2]. This study uses data mining techniques and addresses the vehicle routing problem (VRP) to achieve these objectives. With a dataset encompassing 47 distinct locations requiring waste collection services, the primary goal is to devise an optimized truck route. Additionally, the study aims to analyze the demand for waste collection in different zones and identify peak activity hours. Waste management authorities can allocate resources effectively and optimize the collection process by understanding the spatial and temporal patterns of waste generation. Integrating data mining techniques provides valuable insights into the factors influencing waste generation and collection. Analyzing historical waste collection data and demographic and geographic information can identify patterns and variables affecting waste generation and collection. Clustering and classification techniques aid in identifying zones with higher demand for waste collection services during specific hours [1]. The VRP model is then applied to design efficient collection routes, considering factors such as distance, capacity constraints, traffic patterns, and time windows. The objective is to minimize the number of trucks used, optimize their capacity utilization, and reduce travel distances. Real-time data on vehicle status, traffic conditions, and waste generation rates can be integrated to adjust routes and schedules, improving operational efficiency dynamically. This study aims to provide waste management authorities in Torreon with valuable tools and insights for better waste collection operations. By leveraging data mining techniques and addressing the VRP, waste management practices can be enhanced, reducing environmental impact and a cleaner, healthier living environment for Torreon, Coahuila, Mexico residents.

2. DATA MANAGEMENT

Data management was used to achieve a more efficient waste collection route, and a strategic decision has been made to ignore or delete all data with a demand below 45 persons at the transition point for the waste collection solution being implemented in Torreon, Coahuila, Mexico. By excluding low-demand data at the transition point, we aim to optimize the allocation of resources and streamline the route planning process. Focusing on areas with higher demand allows for better resource utilization and improved service delivery, ensuring that waste collection trucks are deployed where they are most needed [3]. This approach enables us to minimize unnecessary trips to low-demand areas, reduce travel time, and optimize the overall efficiency of waste collection operations in Torreon. By leveraging data-driven decision-making and prioritizing areas with significant demand, we can enhance the effectiveness of the VRP solution and improve the sustainability of waste management practices. We remain committed to maintaining the highest data privacy and protection standards throughout this process.

Adhering to applicable regulations and industry best practices, we ensure the

confidential handling of personal information and safeguard the privacy of individuals involved in the waste collection VRP solution. Through continuously improving data management practices and implementing more efficient routes, we strive to provide a sustainable waste collection service that meets the community's needs while minimizing environmental impact. By optimizing the allocation of resources and focusing on areas with higher demand, we aim to make a positive impact on waste management in the city of Torreon, Coahuila, Mexico. Note that this strategic decision is part of an ongoing effort to enhance waste collection operations and optimize route efficiency in Torreon, aligning with our commitment to providing effective and sustainable waste management solutions for the community.

3. ANALYSIS OF WASTE COLLECTION IN TORREON, COAHUILA, MEXICO

In Torreon, Coahuila, Mexico, efficient waste management is a crucial challenge for maintaining environmental sustainability and public health. A comprehensive waste collection optimization strategy has been developed to address this issue, see Fig. 1. This strategy aims to maximize the efficiency of waste collection routes, minimize costs, reduce environmental impact, and ensure timely and effective waste disposal.

Based on meticulous data analysis, we have identified significant patterns that reveal the peak demand schedule for waste collection services in the city. Our findings indicate that the periods of highest demand occur from 7:30 am to 12 pm and from 6 pm to 8:30 pm, see Fig. 2. This observation can be attributed to the movement of residents commuting to and from work or school during these timeframes [4]. The correlation between the demand spikes and the timing of individuals leaving their workplaces or schools and heading home is crucial in addressing the waste collection route problem. By aligning our routes and schedules with these peak demand periods, we can optimize the efficiency of waste collection operations.

Figure 1. A model of Waste Collection using VRP in Mexico.

Considering the movement patterns in the city during these specific time windows allows us to strategically position our waste collection trucks in areas with the highest concentration of waste generation. Doing so can minimize travel distances, reduce fuel consumption, and optimize the route planning process. Understanding the relationship between daily routines and waste generation patterns is instrumental in designing an effective waste collection system [5]. By leveraging this insight, we can ensure that our services align with the needs and schedules of the community, resulting in improved efficiency and a more sustainable waste management solution. It is worth noting that this data-driven analysis and the subsequent alignment of waste collection schedules with peak demand periods are part of our ongoing efforts to provide the highest quality service to the residents of the city. By continuously monitoring and adapting our route planning strategies based on these insights, we strive to optimize waste collection operations, minimize environmental impact, and enhance the overall efficiency of our services.

No.	Label	Count
1	10:00 a 12:00 pm	102
2	6:38 a 8:12 pm	123
3	7:28 a 9:59 am	105
4	5:00 a 7:27 am	47
5	12:01 a 4:00 pm	99
6	8:13 a 10:47 pm	59
7	4:01 a 6:37 pm	93

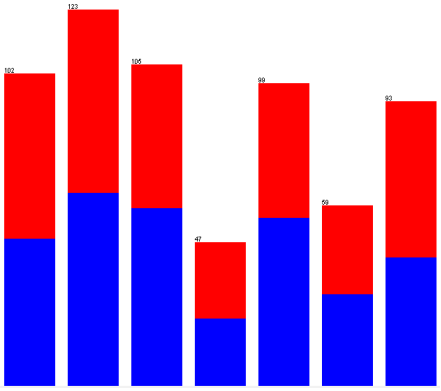

Figure 2. Demand data & Graph.

Upon analyzing the data, we have identified two primary transition points, San Felipe and MEZE School, which consistently exhibit the highest demand in the waste collection system (see Fig. 3). These locations are strategically positioned near areas experiencing significant population growth and urban development in the eastern region of Torreon, Mexico [6]. The demand concentration in this zone indicates the need for a targeted approach in waste collection operations. As the location of newer houses and buildings is an aesthetically appealing part of the city, it is crucial to prioritize cleanliness and waste management efforts in this area. By focusing our resources and optimizing waste collection routes in the eastern region, we can efficiently address the growing demand for waste management services. This strategic approach allows us to provide timely and reliable waste collection services, contributing to a clean and visually pleasing environment for the residents of Torreon.

In summary, identifying San Felipe and MEZE School as transition points with high demand (see Fig. 4) signifies the growth and development in the eastern region of Torreon. Allocating resources and focusing on this zone allows us to optimize waste collection operations, ensuring a clean and sustainable environment for the community.

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No.	Label	
20	Jardines_del_tiempo	13
21	Joyas_Del_Bosque	17
22	Juan_Rulfo	7
23	La_Fuente	14
24	Laguna_Champions	16
25	Marina	15
26	Metalurgica	18
27	MEZE	21
28	Monterreal	18
29	Multideportivo_Oriente	14
30	NARRO	10
31	Nazas	14
32	NOMA	8
33	Nueva_Merced	16
34	Office_Depot	18
35	Parroquia_del_Santo_Cristo	9
36	Pavorreal	12
37	Plaza_del_ECO	12
38	Plaza_Fco_I_Madero	15
39	Quinta_San_Angel	14
40	San_Felipe	25
41	Secundaria_Tecnica_42	14
42	Soriana_Oriente	12
43	Tec_Laguna	13
44	Torreon_Jardin	13
45	Villas_la_Merced	19

Figure 3. Transition Points Data.

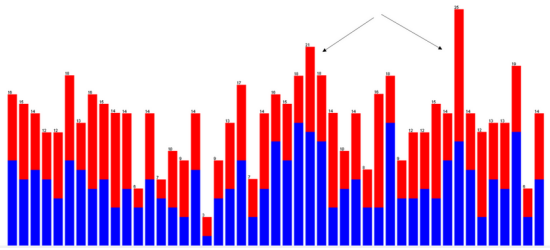

Figure 4. Transition Points Graph.

Based on the dataset, there are approximately 39,009 individuals on the move in Torreon City daily. It is essential to consider the waste generated by these individuals to ensure efficient waste collection. According to the information from the government site, each person analyzed in the dataset generates an average of 994 grams of waste daily. This results in 38.77 tons of waste these individuals generate daily [7]. To address the waste collection requirements of this mobile population, it becomes crucial to design a waste management system that can effectively cover the areas they frequent. This solution includes optimizing the routes and capacities of waste collection trucks to accommodate the waste generated by these individuals during their daily activities. By implementing a VRP (Vehicle Routing

Problem) solution that considers the demand (see Fig. 5), time windows, and truck capacities, we can ensure that the waste collection trucks cover the routes efficiently and have the capacity to pick up all the waste generated in these areas. This solution will help streamline the waste collection process, minimize travel time and distance, and ensure effective waste management for the mobile population in Torreon City.

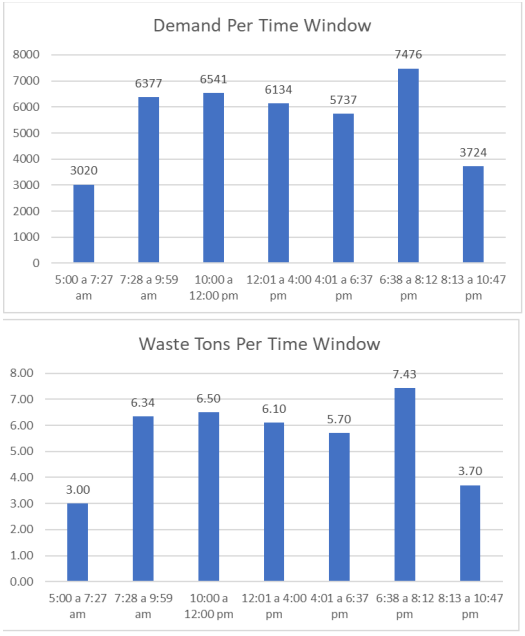

Figure 5. Demand and Waste Tons per Time Window.

3.1. Algorithm used to calculate the routes

In this research, we used the Extended Dijkstra Algorithm to calculate the routes and the effectiveness of the waste collection system; this algorithm has been used successfully for optimal route generation for waste collection [15-16]. The pseudocode is shown below.

3.2. First Time Window 5 - 7:27 am

During the early time window from 5:00 AM to 7:27 AM, our waste collection operations in Torreon, Coahuila, Mexico, will involve deploying two trucks to cover 30 points. It is important to note that only a few workers start their journey to work during this specific time window, resulting in fewer transition points and, consequently, less waste generation [8]. Understanding the lower waste generation during this early time, we have optimized our resources by deploying two trucks to manage the waste collection efficiently. These trucks will cover the designated routes, ensuring prompt collection from all 30 points within the given time frame. By considering the reduced waste generation during this time window and deploying the necessary resources, we aim to provide adequate waste management services. Our goal is to ensure the cleanliness and sustainability of the city while accommodating the lower waste generated during the early morning hours. By deploying the two trucks (see Fig. 6 and Fig. 7), we can effectively address the waste generated during this period and contribute to a clean and well-maintained environment in Torreon.

```
1. Begin:
   a. Create an empty set 'S' (nodes whose shortest
      route has been determined).
   b. Create a set 'Q' that contains all the graph
      nodes.
   c. For each node 'v' in 'Q,' set the distance
      'dist[v]' to infinity and the previous node
      'prev[v]' to undefined.
   d. Set the distance 'dist[start]' from the source
      node 'start' to 0.
2. While 'Q' is not empty:
   a. Select the node 'u' in 'Q' with the shortest
      distance 'dist[u].'
   b. Remove 'u' from 'Q' and add it to set 'S.'
   c. For each neighbor node 'v' of 'u' (consider all
      nodes adjacent to 'u' that are still in 'Q'):
      i. Compute the tentative distance 'alt' as
         'dist[u] + arc_weight(u, v) +
         node_weight(v).'
      ii. If 'alt < dist[v]':
          1. Set 'dist[v] = alt.'
          2. Set 'prev[v] = u' (save the previous
             node on the optimal path to 'v').
3. Once all nodes have been processed (when `Q` is
   empty):
   a. Construct the shortest path from the source
      node 'start' to the destination node 'end'
      using the 'prev' array.
4. End.
```

Figure 6. Truck 1 Route.

3.3. Second Time Window 7:28 a 9:59 am

During the time window from 7:28 AM to 9:59 AM, our waste collection operations in

Torreon, Coahuila, Mexico, will involve deploying three trucks to cover a total of 41 points. It is important to note that most people commute to work during this specific time window, resulting in increased waste generation.

Figure 7. Truck 2 Route.

Understanding the higher waste generation during this period, we have strategically allocated three trucks to manage the waste collection efficiently. These trucks will cover the designated routes, ensuring prompt collection from all 41 points within the given time frame. As people go to work during this time, waste generation increases due to activities such as breakfast, preparation, and packaging waste. By adapting to the increased waste generation and deploying the necessary resources, we aim to provide adequate waste management services [9]. Our goal is to ensure the cleanliness and sustainability of the city while accommodating the higher waste generated during the morning commute hours. With the deployment of the three trucks (see Figs. 8, 9, and 10), we can effectively address the waste generated during this period, specifically related to the morning rush hour, and contribute to a clean and well-maintained environment in Torreon.

Figure 8. Truck 1 Route.

3.4. Third Time Window 10:00 a 12:00 pm

During the time window from 12:01 PM to 4:00 PM, our waste collection operations in Torreon, Coahuila, Mexico, will involve deploying three trucks to cover 40 points. It is important to note that various activities, including lunch breaks and increased waste generation in specific locations, characterize this time window.

Figure 9. Truck 2 Route.

Figure 10. Truck 3 Route.

Understanding the dynamics of this period, we have allocated three trucks to manage waste collection efficiently. These trucks will cover the designated routes, ensuring prompt collection from all 40 points within the given time frame. During this time, lunch breaks and other activities generate more waste in certain areas. We have optimized our resources to address this increase and provide effective waste management services. Additionally, we are closely monitoring the demand, and in the event of a noticeable increase, we are prepared to deploy a fourth truck to ensure the timely collection of waste. By considering the unique characteristics of this time window and deploying the necessary resources, we aim to provide efficient waste management services [10]. Our goal is to ensure the cleanliness and sustainability of the city during this period of increased waste generation. With the deployment of the three trucks (see Figures 11, 12, and 13) and the readiness to introduce a fourth, if needed, we can effectively address the waste generated during this period and contribute to a clean and well-maintained environment in Torreon.

Figure 11. Truck 1 Route.

Figure 12. Truck 2 Route.

Figure 13. Truck 3 Route.

3.5. Fourth Time Window 12:01 a 4:00 pm

During the extended time window from 12:01 PM to 4:00 PM, our waste collection operations in Torreon, Coahuila, Mexico, will involve deploying four trucks to cover a total of 39 points. This time window is characterized by higher demand and specific locations that generate more waste. Additionally, it is worth noting that many workers take their lunch breaks during this period, resulting in increased waste generation. Considering the higher waste production during lunch hours, we have strategically allocated additional resources and optimized the routes of our trucks to accommodate the increased waste generation at these specific points [11]. By doing so, we can efficiently manage the waste accumulation and ensure prompt collection to maintain cleanliness and hygiene in the city. Our dedicated approach to waste collection during this time window aims to address the unique demands and challenges posed by the increased waste generation from lunch breaks. By deploying the four trucks (see Figures 14, 15, 16, and 17) and adjusting their routes accordingly, we can provide timely waste management services and contribute to a clean and well-maintained environment in Torreon.

Figure 14. Truck 1 Route.

Figure 15. Truck 2 Route.

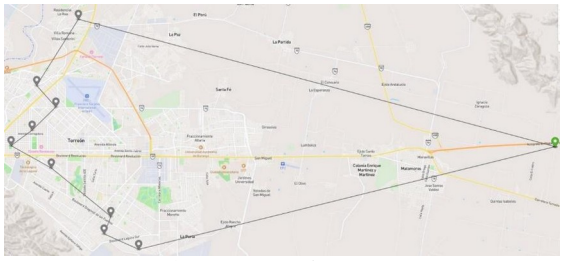

Figure 16. Truck 1 Route.

Figure 17. Truck 2 Route.

3.6. Fifth Time Window 4:01 a 6:37 pm

During the time window from 4:01 PM to 6:37 PM, our waste collection operations in Torreon, Coahuila, Mexico, will involve deploying three trucks to cover a total of 39 points. It is important to note that some workers start their journey home during this specific time window, resulting in increased waste generation. Understanding the increased waste generation during this period, we have allocated three trucks to manage waste collection efficiently. These trucks will be strategically deployed to cover the designated routes and ensure prompt collection from all 39 points within the given time frame. By adapting to the unique dynamics of this time window and deploying

the necessary resources, we aim to provide adequate waste management services [12]. Our goal is to ensure the cleanliness and sustainability of the city while accommodating the increased waste generated during the workers' commute hours. With the deployment of the three trucks (see Figures 18, 19, and 20), we can effectively address the waste generated during this period and contribute to a clean and well-maintained environment in Torreon.

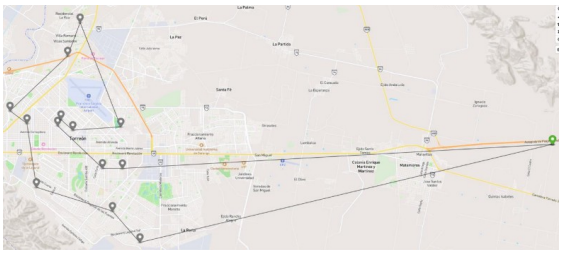

Figure 18. Truck 1 Route.

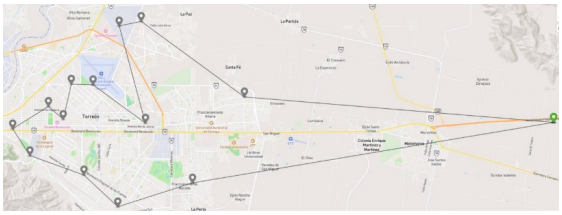

Figure 19. Truck 2 Route.

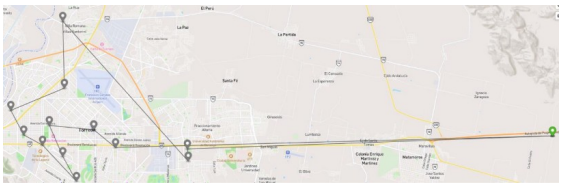

Figure 20. Truck 3 Route.

3.7. Sixt Time Window 6:38 to 8:12 pm

During the time window from 6:38 PM to 8:12 PM, our waste collection operations in Torreon, Coahuila, Mexico, will involve deploying four trucks to cover a total of 44 points. This time window is characterized by various activities, including the evening rush hour and increased waste generation from households and commercial establishments. Understanding the dynamics of this period, we have allocated four trucks to manage waste collection efficiently. These trucks will cover the designated routes, ensuring prompt collection from all 44 points within the given time frame. During the evening rush hour, an increased volume of waste is generated from activities such as dinner preparation, packaging waste, and household waste accumulation. By deploying four trucks (see Figures 21, 22, 23, and 24), we can effectively address the higher waste generation and provide timely waste management services.

Figure 21. Truck 1 Route.

Figure 22. Truck 2 Route.

Figure 23. Truck 3 Route.

Figure 24. Truck 4 Route.

We recognize the importance of addressing waste during this time window when households and businesses generate a significant amount of waste. Our dedicated approach to deploying four trucks enables us to manage waste collection efficiently and maintain a clean and well-maintained city environment. By optimizing our resources and closely monitoring the waste generation levels, we aim to meet the demands of this time window. Our goal is to ensure timely waste collection, promote sustainability, and

contribute to a clean and thriving environment in Torreon.

3.8. Last Time Window 8:13 a 10:47 pm

During the final time window from 8:13 PM to 10:47 PM, our waste collection operations in Torreon, Coahuila, Mexico, will involve deploying three trucks to cover 33 points. It is important to note that during this specific time window, there is a decrease in waste generation due to reduced activity and quieter hours. Understanding the reduced waste generation during this period, we have allocated three trucks to manage the waste collection efficiently. These trucks will cover the designated routes, ensuring prompt collection from all 33 points within the given time frame. As the evening progresses, activities and waste generation decrease. This includes decreased household waste as individuals settle down for the night and reduced commercial waste as businesses wind down their operations. We can provide effective waste management services while optimizing efficiency by adapting our resources to match the lower waste generation during this range of time. Our dedicated approach during this time window focuses on maintaining cleanliness and waste management services in alignment with reduced waste generation [13]. By deploying the three trucks (see Figures 25, 26, and 27), we can effectively address the remaining waste and contribute to a clean and well-maintained environment in Torreon.

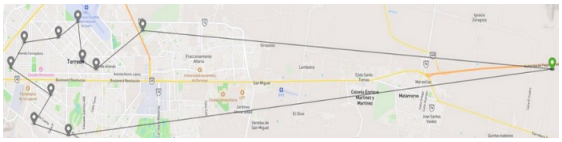

Figure 25. Truck 1 Route.

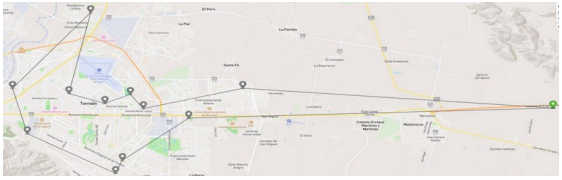

Figure 26. Truck 2 Route.

Figure 27. Truck 3 Route.

With the deployment of the three trucks and our understanding of the decreased waste generation during this time window, we ensure timely waste collection while being mindful of resource optimization. We aim to provide efficient waste management services and contribute to the sustainability of Torreon during these quieter hours of the evening.

Our waste collection operations in Torreon, Coahuila, Mexico, involve deploying multiple trucks to cover various time windows and routes. It is evident that early morning and late afternoon are periods when we observe increased mobility in the city, leading to higher waste generation. However, it is crucial to note that waste generation varies throughout the day due to different activities and routines. To ensure a clean city environment, we have strategically allocated our resources, including the deployment of trucks and optimization of routes, to cover all time windows and address the corresponding waste generation. This approach allows us to effectively manage waste collection and meet the demands of each specific time window. Fig. 28 shows that the waste generation levels fluctuate throughout the day, with noticeable peaks during the early morning and late afternoon periods [14]. By analyzing this data, we have adjusted our operations to allocate additional resources during these peak times to handle the increased waste generation adequately. Overall, our waste collection strategy aims to accommodate the varying waste generation patterns and maintain cleanliness in Torreon throughout the day. We understand the importance of providing efficient waste management services to keep the city clean and sustainable. By considering the unique characteristics of each time window, monitoring waste generation, and

deploying the necessary resources, we are committed to delivering timely waste collection services and contributing to a clean and well-maintained environment in Torreon.

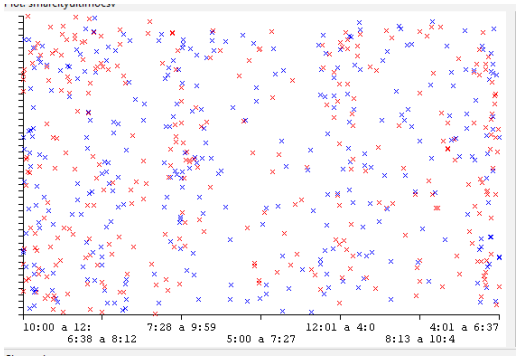

Figure 28. Distribution of demand in the Smart City.

Indeed, one of our key objectives in implementing these waste collection strategies is to increase the satisfaction level of the residents in Torreon. We recognize that people may have diverse opinions and thoughts about the waste collection system, as shown in Fig. 29. By optimizing our waste collection operations, addressing peak waste generation periods, and ensuring timely and efficient services, we aim to provide a better quality of life for the people of Torreon. We understand that a clean and well-maintained city environment contributes to satisfaction and well-being. Through our efforts, we strive to exceed expectations, aligning our waste collection services with the needs and expectations of the residents (see Fig. 30). We value feedback and continuously work towards improving the waste collection system to meet the demands and ensure a higher level of satisfaction among the people of Torreon.

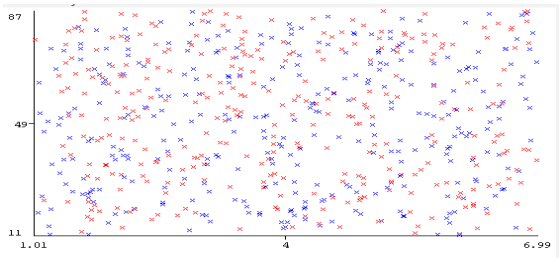

Figure 29. Actual Demand in a Smart City.

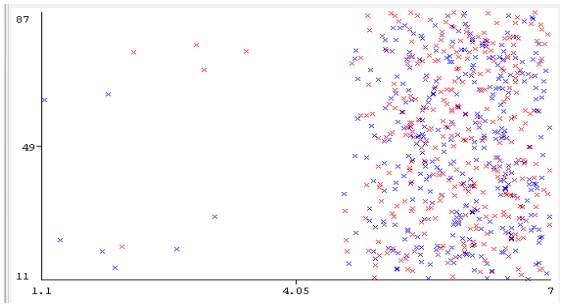

Figure 30. Satisfaction Projected after implementation of VRP for Waste Collection.

CONCLUSIONS

After analyzing waste collection using the Vehicle Routing Problem approach, we can draw the following conclusions: Optimization Efficiency: Using VRP algorithms can significantly improve the efficiency of waste collection operations. By optimizing the routes and schedules for waste collection vehicles, VRP can reduce travel distances, minimize fuel consumption, and enhance overall operational efficiency. Cost Reduction: Implementing VRP in waste collection can lead to cost savings for waste management companies and municipalities. By optimizing the allocation of resources and minimizing travel distances, VRP can help reduce labor costs, fuel expenses, and vehicle maintenance costs. Environmental Impact: VRP can contribute to minimizing the environmental impact of waste collection. By optimizing routes, it reduces vehicle emissions and fuel consumption, resulting in a lower carbon footprint and improved air quality in urban areas. Service Quality: VRP algorithms can enhance the quality of waste collection services. By optimizing routes, VRP ensures timely and efficient waste collection, reducing the chances of missed or delayed pickups. This approach improves customer satisfaction and overall service quality. Scalability: VRP can handle waste collection operations of varying scales, from small neighborhoods to entire cities. The proposed methodology can adapt to changing waste generation patterns, route constraints, and vehicle capacities, making it a flexible and scalable solution for waste management. Integration with Technology: VRP can be

integrated with other advanced technologies such as Internet of Things (IoT) sensors, GPS tracking, and real-time data analysis. This integration allows for dynamic route adjustments, efficient scheduling, and proactive maintenance, further improving waste collection operations. Decision Support: VRP algorithms provide decision support tools for waste collection managers. By generating optimal routes and schedules, VRP enables managers to make informed decisions, allocate resources effectively, and respond quickly to changing operational requirements. Applying VRP to waste collection operations offers numerous benefits, including improved efficiency, cost reduction, environmental sustainability, enhanced service quality, scalability, and decision support. It represents a promising approach for optimizing waste management processes and improving overall waste collection systems.

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