September 2025, Vol:3, Issue:2

International Journal of New Findings in Engineering, Science and Technology

journal homepage: https://ijonfest.gedik.edu.tr/

Received:14.03.2025 Accepted:04.08.2025 Pablished:29.09.2025

The Firefighting and Rescue Wagon Design

İsmail Cihan Satılmış[a*], Egemen Sulukan[b], Doruk Gürkan[c]

*[a]Department of Mechanical Engineering, Istanbul Gedik University, Türkiye icihan7@gmail.com (*Corresponding Author)*
[b]Department of Mechanical Engineering, Istanbul Gedik University, Türkiye egemen.sulukan@gedik.edu.tr
[c]Department of Mechanical Engineering, Istanbul Gedik University, Türkiye dorukgrkan@yahoo.com

Abstract

The Firefighting and Rescue Wagon (FRW) is designed as a multifunctional emergency response vehicle for railway transportation accidents, such as fires, explosions, and chemical leaks. This specialized wagon aims to ensure the safe rescue and evacuation of passengers, provide temporary secure storage for hazardous materials, and minimize potential environmental damage. Additionally, it offers the capability to swiftly implement environmental safety measures and conduct effective rescue operations in disaster areas. The wagon provides a unique advantage, particularly in areas where road access is not possible, including railway corridors, bridges, and tunnels. It has been specifically developed for use in locations where conventional rescue and firefighting vehicles cannot reach. This enables rapid response to sudden incidents like fires and supports rescue teams in working safely within the disaster zone.

Keywords: Firefighting, Rescue, Wagon, Design, Railway.

1. INTRODUCTION

The design of the Firefighting and Rescue Wagon is of great importance for responding quickly and effectively to emergencies and disasters that may occur during railway transportation activities [1]. This specialized design prioritizes the safe and secure transportation of passengers, personnel, the environment, and the cargo key elements of railway transportation throughout the journey. Additionally, the various types of wagons and superstructures used in railway transport provide a strong foundation for the development of such a design.

Emergency response vehicles based on rail systems have appeared in various forms throughout history. Firefighting and first aid trains used in Australia between 1918 and 1990 were eventually decommissioned as road ambulance services evolved [2]. Similarly, hospital trains were first developed during Crimean War and have since served as mobile health centers in many subsequent crisis [3]. Even today, railway ambulances operating in Russia's Siberian region and India continue to meet the need for mobile medical services [4]. Unlike these historical examples, the FRW stands out as an integrated system that combines not only health services but also fire suppression, rescue, evacuation and environmental protection functions [5].

FRW contains many features that are not offered by standard fire response vehicles. With its high-capacity water and foam tanks, extensive equipment storage space and versatile rescue tools, this wagon enables effective intervention in remote or hard-to-access areas of the railway network. It provides a unique solution for firefighting and rescue operations, especially in forested areas, bridges, tunnels and other locations where road access is not possible [6]. FRW is the first of its kind in

https://doi.org/10.61150/ijonfest.2025030203

Türkiye—a multifunctional intervention vehicle specifically developed for railway infrastructure. This innovative solution allows for effective response in areas where road access is not possible, particularly bridges, tunnels, valleys and mountainous terrain. In emergencies such as fires, explosions, or chemical leaks that may occur during railway transportation, FRW can operate independently in areas inaccessible to traditional firefighting and rescue vehicles. In this sense, it represents a revolutionary development not only for railways but also for disaster and emergency management.

Being the first of its kind in Turkey and within the railway system, FRW is unique not only technically but also strategically. With its high-capacity water and foam tanks, advanced rescue and evacuation equipment and command center infrastructure, the wagon can perform the functions of six separate fire trucks. Furthermore, by traveling directly via rail to hard-to-reach areas, it provides a major advantage in time-critical rescue operations. This special wagon functions not only as an intervention vehicle but also as a mobile command and coordination center during emergencies. By transporting all necessary equipment and personnel to the scene, it ensures that response efforts are carried out swiftly, systematically and effectively.

FRW is a pioneering vehicle that elevates safety and response capacity within the railway system to a higher level through a concept being implemented for the first time in Türkiye. It saves lives, protects the environment and minimizes losses by intervening in areas unreachable by road vehicles. Representing a key step in Türkiye’s disaster preparedness vision, FRW is poised to become a cornerstone of next-generation railway safety. Ultimately, FRW is an innovative project that will make a significant contribution to Türkiye’s developing railway infrastructure and transportation sector. Equipped with modern technology such as CAD-based virtual design and clearance testing, high-capacity water pumps and remote-controlled water monitors, an onboard generator system with 24-hour autonomous operation, advanced heating systems for ISO tanks, and an integrated control room with computers and camera surveillance, this wagon will play a critical role in enhancing railway safety while reducing environmental and human risks. In the future, the widespread adoption of such specialized designs will enable higher safety standards in railway transportation and foster the development of rapid, effective disaster response solutions. FRW is an innovative project that will make a significant contribution to Türkiye's developing railway infrastructure and transportation sector.

2. METHODOLOGY

The initial and latest design of FRW is shown in Figure 1 and 2, respectively. In developing this design, the project's purpose and the product's scope were carefully considered. FRW has been designed to provide a much larger capacity and area of coverage compared to conventional firefighting vehicles. When compared with standard emergency vehicles, it matches the water capacity of 30 First Response units, the foam capacity of 13 Response units, and the rescue equipment capacity of 5 Response units. A comparison table is presented in Figure 3 and Table 1.

Figure 1. Fire Fighting and Rescue Wagon Initial Design.

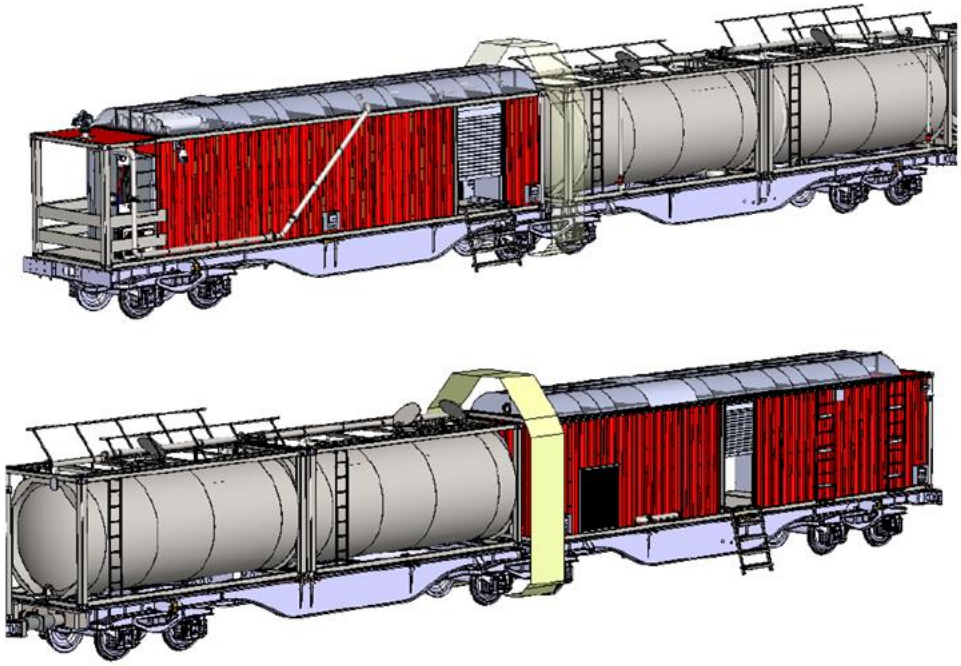

Figure 2. Fire Fighting and Rescue Wagon Latest Design.

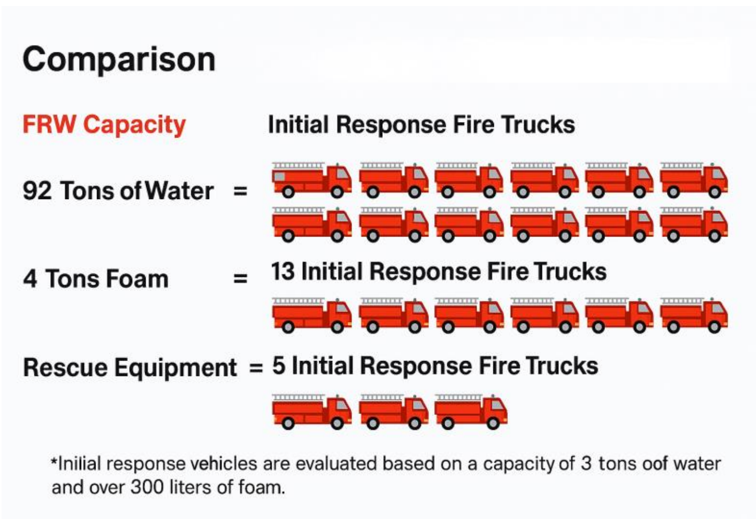

Figure 3. FRW and Fire Truck Capacity Comparison (Manufacturer company comparison).

Moreover, FRW is equipped with derailment tools, which are not typically found on every response vehicle. “Derailment” refers to a train coming off the rails. This feature is one of FRW's most powerful advantages. Since it operates on railways and carries derailment equipment onboard, it offers a capability that is rare in traditional firefighting vehicles making it a standout and preferred choice among emergency response tools.

The initial FRW design consisted of two units: a 40-foot Equipment Container and a 20-foot Power Unit, covering a total area of 120 feet. This design had a capacity of 68 tons of water and 4 tons of foam. After the equipment was put into active use, improvements were made to enhance the design, resulting in the current version. Compared to the previous design, the updated model has been expanded by approximately 30%, making it more comprehensive and user-friendly. The earlier design is illustrated in Figure 1. In the latest version, the FRW has been mounted on two 80-foot platform wagons, increasing the total area to 160 feet. Once the installation of the equipment is completed, the system is configured to operate as a single, unified unit.

FRW can also generate its own electricity, allowing for continuous operation for up to 24 hours. To achieve this, it is equipped with two diesel tanks. These tanks have sufficient capacity to operate the generator and the pump for a full 24-hour period.

Table 1. FRW and Fire Truck Capacity Comparison (Manufacturer Comparison)

2.1.1.1. FRW Capacity	**2.1.1.2. Equivalent Initial Response Fire Trucks**	**2.1.1.3. Units**
2.1.1.4. 92 Tons of Water	2.1.1.5. 30 Fire Trucks	2.1.1.6. 30 Units
2.1.1.7. 4 Tons of Foam	2.1.1.8. 13 Fire Trucks	2.1.1.9. 13 Units
2.1.1.10. Rescue Equipment	2.1.1.11. 5 Fire Trucks	2.1.1.12. 5 Units

The entire design was created virtually using SolidWork**s** software and all manufacturing details were derived from this program. On SolidWorks, the entire design was modeled to exactly match the real-life implementation, with the aim of eliminating potential issues that could arise before, during, or after production. Another advantage of the software is its ability to assist in preparing the technical drawings required for manufacturing.

The design created in SolidWorks also provided a virtual testing opportunity for the clearance (gauge) test, with the part shown in yellow in Figures 2 and 4. The clearance test is one of the final evaluations for railway products and is conducted to simulate the product's entry into a tunnel. The primary objective of this test is to determine whether any part of the product might come into contact with the tunnel walls during entry, passage, or exit. If any part makes contact, the test is considered a failure, and necessary revisions must be made before it can be repeated. The tunnel simulation prepared for the test measures 3150 mm in width and 4520 mm in height.

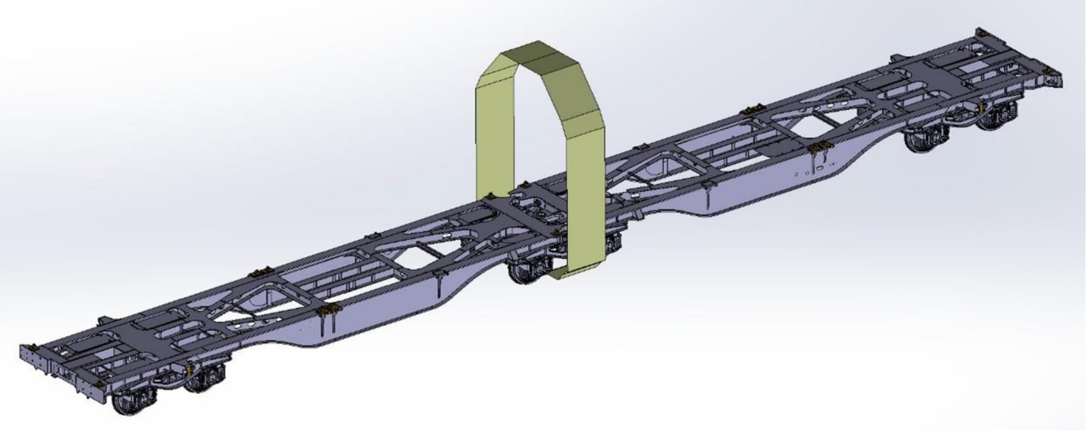

Figure 4. 80 FT Platform Wagon.

For FRW design, the clearance test was simulated using SolidWorks and potential issues were resolved within the software. For example, the guardrails of the ISO tanks initially failed the test. To pass, the guardrails were redesigned to be movable. Detailed measurements of this revision are provided in Figures 5 and 6. In the test supported by visual evidence, it was clearly observed that the fixed guardrails exceeded the clearance limits. However, the guardrails were clearly seen to remain within the permitted gauge boundaries.

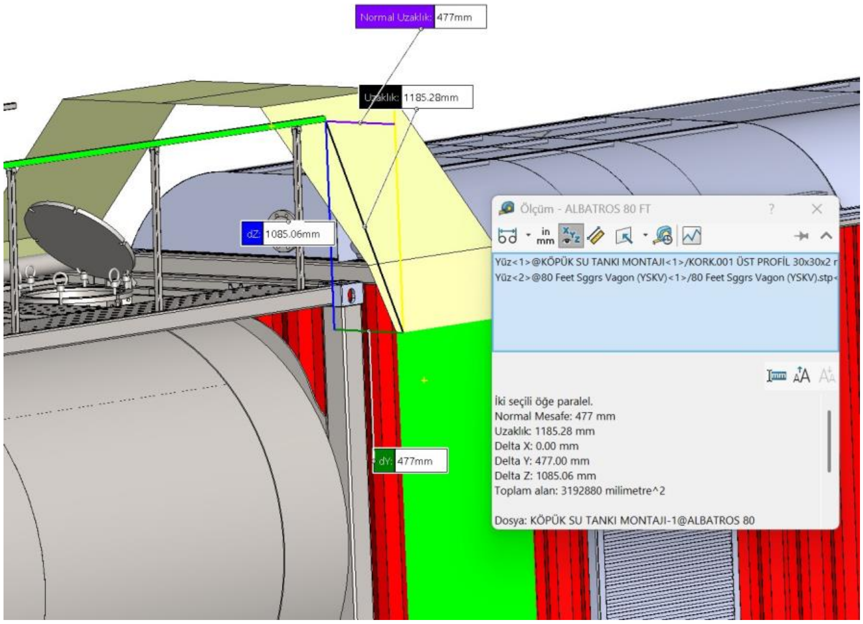

Figure 5. Guardrail arrangement on ISO tank prior to envelope (clearance) testing.

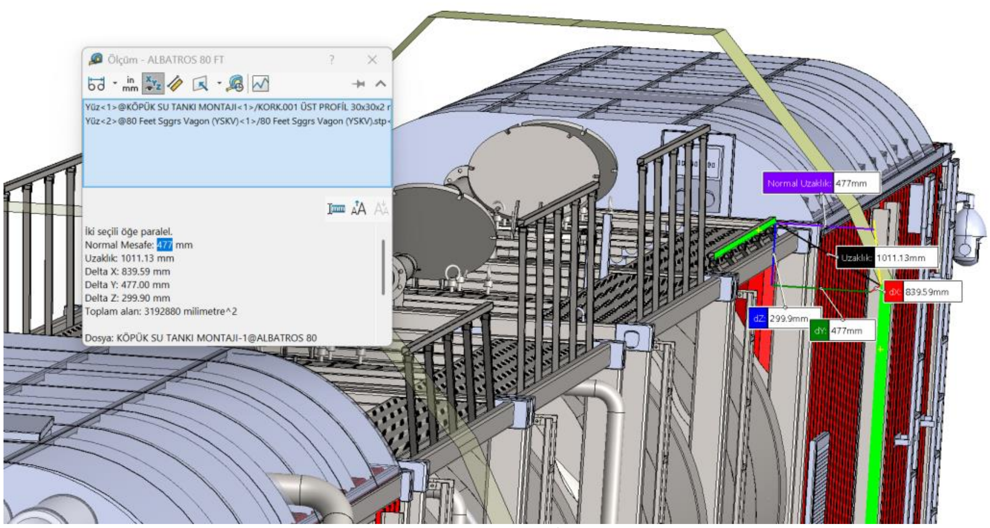

Figure 6. Guardrail arrangement on ISO tank following envelope clearance testing.

During the design process, preliminary research and objectives were considered. Previously manufactured products were examined and scenarios aligned with the project scope and objectives were taken into account.

Primary Objectives of the Firefighting and Rescue Wagon Design:

- **Ensuring Environmental Safety**

  During and after disasters, environmental safety measures are taken to protect people, nature, animals, and other assets.

- **Firefighting**

  FRW is designed as an integrated system with high firefighting efficiency using water and foam-based solutions. Extinguishing agents stored in ISO tank containers are delivered to the fire zone in a controlled and powerful manner through high-capacity pumps and monitors. This innovative system enables rapid and effective fire intervention in railway transportation and industrial areas, maximizing life and property safety [7].

- **Rescue and Emergency Response**

  It is designed for effective use in railway accidents, derailments, collisions, and other emergency scenarios.

- **Environmental Pollution Prevention and Mitigation**

  One of the key accident scenarios involves preventing fuel leaks in derailed wagons. In case of tank wagon derailments, minimizing fuel or chemical spills and controlling leaks to reduce environmental damage is of utmost importance.

- **Temporary Hazardous Material Storage**

  In railway transportation, accidents involving tank wagons carrying hazardous and flammable liquids pose significant environmental risks [8]. In the event of such accidents, the uncontrolled release of transported liquids increases the risk of fire, threatening both environmental and life safety.

The Firefighting and Rescue Wagon Design consists of three main structures.

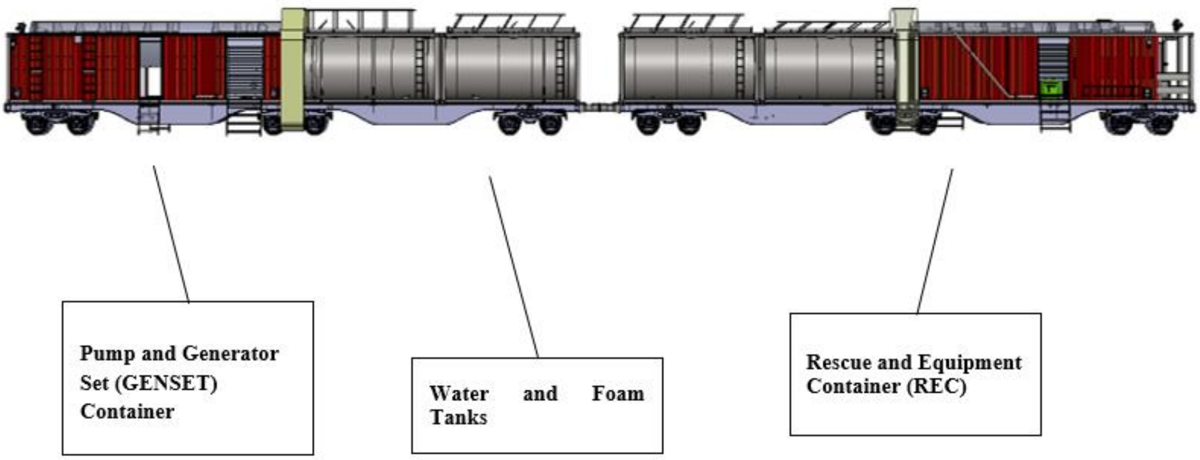

Figure 7. Three Main Structures of the Firefighting and Rescue Wagon Design.

FRW Design consists of two 40 FT containers and four 20 FT ISO tank containers. One of the 40 FT containers is designated as the Pump and Generator Set Container (GENSET), while the other is named the Rescue and Equipment Container (REC). The layout plan is shown in Figure 7.

2.1 Pump and Generator Set (GENSET) Container

Half of the container is designed for the pump and generator units, while the remaining section is designated as an equipment room. GENSET Container is the primary and essential container set that supplies all the energy for FRW Design. No one other than the assigned personnel should interfere with GENSET. Given that the generator unit is considered the heart of the system, it is crucial to keep it isolated from everything else. The generator unit is an indispensable component that ensures the effective operation of the entire system. For the equipment within this system to function properly, the generator must be operational.

The pump unit is the most critical component used in the firefighting process of FRW Design. It is responsible for pressurizing and distributing water through all pipelines within the system. The primary reason for housing both the generator and the pump in the same container is that they are connected to shared diesel fuel tanks. To avoid extending the fuel lines further, these two key components are placed within a single container. Figure 8 and 9 show placement of the pump and generator set container and pump and generator room, respectively.

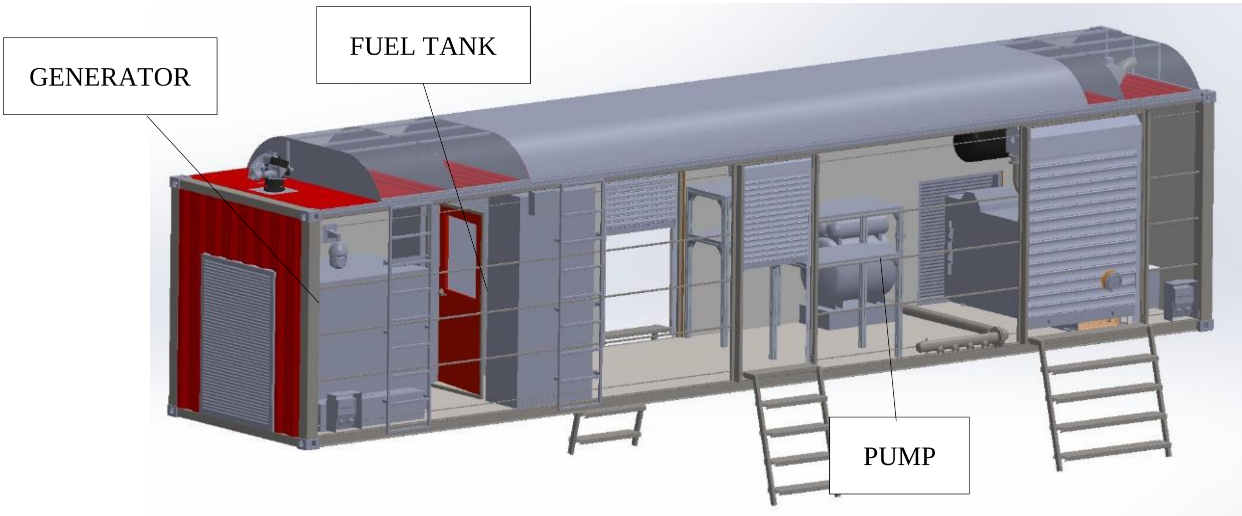

Figure 8. Placement of the Pump and Generator Set Container (GENSET).

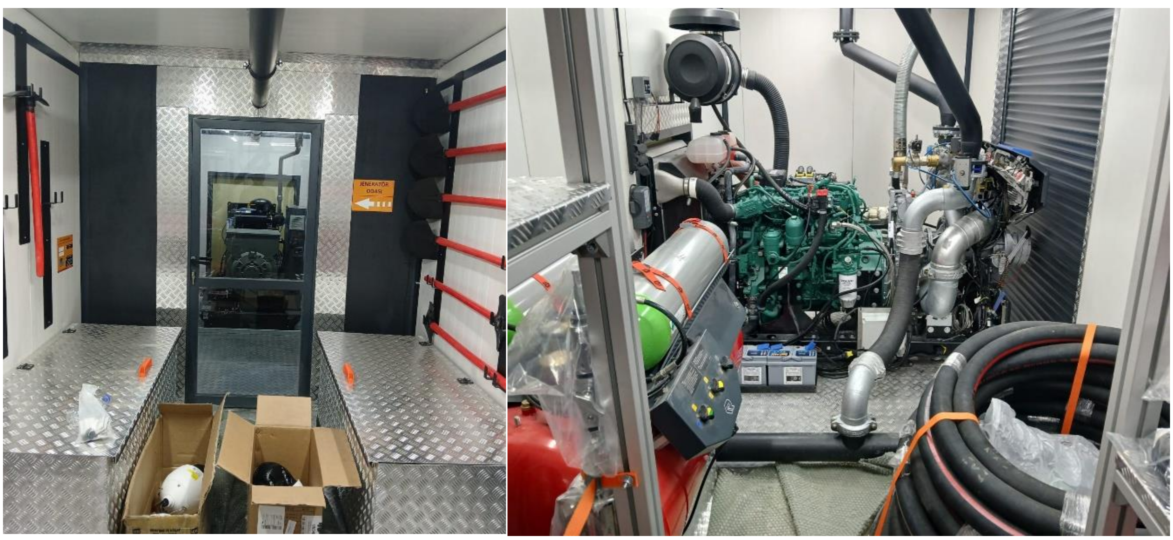

Figure 9. Pump and Generator Room (GENSET).

2.2 Water and Foam Tanks

FRW Design includes four 20 FT ISO tanks, where water and foam will be stored. Three of these ISO tanks are designed as single-chamber water tanks, while one tank is divided into two chambers, one for water and the other for foam. ISO tanks will be exposed to all kinds of weather conditions. To prevent water from freezing in cold climates, all tanks are equipped with resistant heaters. The electrical output of these heaters are connected to a single circuit leading to the control room. The heaters can be operated based on weather conditions via computers in the control room. To ensure a continuous water flow, all four tanks are connected in series without any interruptions. This setup prevents the pump from drawing air and causing cavitation [9]. Although the pump is designed with advanced technology to minimize this risk, connecting all tanks in series provides an additional safety measure. Breather valves are installed on each tank to allow air in during suction and prevent pressure drop. [10]. These breather valves allow extra air to enter the tank during suction, eliminating vacuum risk and protecting the tanks.

Two different materials are used in the production of the ISO tanks: carbon steel for the structural frame and stainless steel for the tank section. Carbon steel is chosen for the construction due to its high strength and cost-effectiveness, making the tanks more resistant to external impacts and environmental conditions. Additionally, the widespread use of carbon steel in manufacturing simplifies the supply process and helps reduce production costs. Figure 10 shows pump and generator set and 20FT ISO tank containers.

Figure 10. Pump and Generator Set and 20FT ISO Tank Containers.

2.3 Rescue and Equipment Container (REC)

The control room and personnel compartment are equipped with computers, control units and a camera system, allowing full control of FRW. Additionally, all personal protective equipment (PPE) required for 12 personnel will be stored in this room. The control room is structured to accommodate a fully equipped manager and 12 fully equipped firefighting/rescue personnel.

The control room is built to be completely gas-tight and insulated accordingly. It also features a separate breathable air supply system that maintains positive pressure within the room. This ensures that breathable air is available inside the wagon without the need for protective masks [11]. Another key purpose of this system is to create a suitable working environment for the manager, who will be overseeing the entire operation from inside the control room (Figure 11).

All equipment stored on the shelves is securely fastened to prevent movement while the wagon is in transit (Figure 12). There will be two doors at the beginning and end of the shelving system. A jib crane will be positioned at these doors to facilitate the loading and unloading of equipment. Additionally, an overhead crane will be installed between the shelves to assist in moving heavy items, ensuring compliance with occupational health and safety measures [12]. Furthermore, a fixed compressor will be located in this area to maintain positive pressure. Rescue and equipment container miscellaneous material list was given in Table 2.

Figure 11. Control Room and Staff Compartment.

Table 2. Rescue and Equipment Container Miscellaneous Material List.

Serial No	Equipment Name	Description
1	Flame-Resistant Aluminized Suit	Special protective suits for fire rescue and gas fire valve closures. Reflects 85%-95% of radiant heat from a 1000°C heat source, protecting firefighters from extreme heat [13]. 
2	High-Durability Gas-Tight Chemical Protective Suit	Gas-tight suit for use with a compressed air breathing apparatus, protecting against hazardous gas, aerosol, liquid and solid substances. Offers mechanical durability and is suitable for cold environments [14]. 
3	Megaphone	Used for warnings and communication during emergency responses.
4	Firefighter Hose	Ensures water delivery to the required area during firefighting [15]. 
5	Hydrant Wrenches	Used to supply water from fixed hydrants for firefighting.

6	Rechargeable Lighting Devices	Provides illumination in areas with insufficient lighting [16].
7	Warning Tapes	Restricts civilian access to emergency response areas and provides warnings.
8	Hydraulic Cutter	Essential for freeing trapped victims in traffic accidents. Cuts through steel and metal parts for fast and safe rescues [17]. 
9	Hydraulic Ram	Used for lifting and expanding large objects. Creates safe exit routes for trapped individuals [18]. 
10	Hydraulic Spreader	Separates and expands trapped objects in emergencies. Used with hydraulic cutters to enlarge rescue areas [19]. 
11	Firefighter Breaking & Piercing Hand Tools and Rescue Saws	Allows teams to access trapped individuals, overcome obstacles in fires and disasters and perform life-saving interventions [20]. 
12	Lifting Bags	High-pressure air-inflated bags used to lift heavy objects and rescue trapped individuals under debris or vehicles. 
13	Cable Reels	Provides power for lighting and electrical devices during emergency operations.

Figure 12. Rescue and Equipment Container Storage Area Shelf Example.

For the design of the material shelves to be used inside the container, a material selection has been made to enhance both durability and ease of use. In this regard, aluminum has been chosen to produce the shelves [21]. One of the most important factors in selecting aluminum is its lightweight nature and high strength. Compared to heavy metals such as steel, aluminum has a significantly lower weight while still being strong and durable [22]. This ensures the creation of a sturdy and reliable shelving system without increasing the overall weight of the container.

Additionally, aluminum's natural resistance to rust and corrosion provides a significant advantage in terms of long-term use [23]. The shelf system is designed to remain secure and durable for at least 30 years. Aluminum's durability is a key criterion to prevent wear and shear caused by external factors over time. As a result, maintenance requirements for the shelves are minimized, operational costs are reduced and a long-term, sustainable solution is provided.

3. RESULT

The previously manufactured FRW has been thoroughly examined in detail. In this study, the strengths of the existing design, areas that need improvement or modification and any potential defects were identified. A comprehensive analysis was conducted, considering the product's application areas, operational efficiency and user requirements.

The design process of FRW began with a thorough analysis of the previous version, was improved based on user needs and underwent detailed evaluations before proceeding to production. Throughout the manufacturing process, quality control mechanisms were actively implemented, ensuring strong coordination between the design and production stages. As a result, an efficient, durable and user-friendly product that meets both technical and operational requirements was developed.

FRW Design, produced with domestic and national capabilities, is positioned on two wagons with a total length of approximately 53 meters. A total of two wagons are designed with 2 units of 40 ft containers and 4 units of container tanks. In the distribution on a single wagon, 1 unit of 40 ft container and 2 units of 20 ft container tanks are designed.

- Thanks to its fuel tanks and onboard generator, the FRW can operate autonomously and provide uninterrupted intervention for up to 24 hours.
- FRW has the capacity to carry 30 First Response Vehicles with 92 tons of water.

- FRW has the capacity to carry 13 Intervention Vehicles with 4 tons of foam.
- It has the capacity to carry 5 Intervention Vehicles with the equipment in the storage area of the Rescue and Equipment Container.
- FRW Design is designed to have a power capacity of 70 kVA. This ensures that all electrical devices within the system are powered and ready for operation. Additionally, it will be able to provide lighting for the surrounding area to ensure environmental safety and security.
- The system's pump ensures a continuous water pressure of 10 bar.
- The system features remote-controlled water monitors, allowing for water spraying up to 100 meters ahead, significantly expanding the intervention area.
- Thanks to the fixed water lines along the wagon and the portable hoses in the containers, the system will be able to reach up to 500 meters from both sides of the wagon, providing the ability to intervene over a large area.
- The equipment stored inside the containers provides the possibility of accident rescue and recovery.
- FRW provides opportunities for preventing and eliminating environmental pollution.
- FRW provides temporary storage options against accidents and hazards that may occur during the transportation of hazardous chemicals, ensuring the safe containment of the load, minimizing environmental damage, and reducing potential harm.
- FRW ensures the safety of the cargo on the railways.
- FRW allows for increased preventive measures and intervention possibilities in facilities, storage and factory areas, shipyards, ports and similar locations along the railway route.

The latest design has been developed with an approximately 30% higher capacity compared to the first prototype of FRW, which was produced and put into operation in 2021. The primary goal of increasing the design's capacity was to enhance the water capacity and impact radius. In this way, the design has been optimized to achieve greater efficiency with 30% more capacity than the prototype.

After the earthquakes on February 6, FRW was used for the first time during the fire at the Iskenderun Port. It operated day and night for several days, playing a key role throughout the entire operation. During its operation, the pump on the system drew water from the sea, providing a continuous and unlimited water supply. This allowed the water monitors on the wagon as well as the fire trucks' water tanks to be continuously filled.

Acknowledgements

This research article is derived from the master's thesis titled "Yangın Söndürme ve Kurtarma Vagonu Tasarımı". The authors would like to thank Albatros Kreatif Mühendislik A.Ş. and Selahattin Nevzat Şenocak for their support throughout the study. Additionally, the authors declare that they have not received any financial support from any institution, organization, or individual during the research process.

Authors' Contributions

No	Full Name	ORCID ID	Author’s Contribution
1	İsmail Cihan Satılmış	0009-0008-7300-5247	1,2,3,4,5
2	Egemen Sulukan	0000-0003-1138-2465	1,2,3,4,5
3	Doruk Gürkan	0000-0001-8507-8592	1,2,3,4,5
1- Study design 2- Data collection 3- Data analysis and interpretation 4- Manuscript writing 5- Critical revision			

References

[1] Shojaei, F., Qaraeian, P., Firoozbakht, A., Chhabra, D., & Jahangiri, K., 2023. The necessity for an integrated Emergency Operations Center (EOC) among first responders: Lesson learned from two Iranian railway accidents. Heliyon, 9(5).
[2] Bowden, B., 2017. An exploration into the relationship between management and market forces: The railroads of Australia and the American West, 1880-1900. Journal of Management History, 23(3), 297-314.
[3] Bektas, Y., 2017. The Crimean War as a technological enterprise. Notes and Records: The Royal Society Journal of the History of Science, 71(3), 233-262.
[4] Miettinen, R., 2008. Market Potential of Northwest Russia for Telemedicine Applications. Lappeenranta University of Technology, Northern Dimension Research Centre.
[5] Brown, H. A., Douglass, K. A., Ejas, S., & Poovathumparambil, V., 2016. Development and implementation of a novel prehospital care system in the state of Kerala, India. Prehospital and disaster medicine, 31(6), 663-666.
[6] Long, A. J., Wade, D. D., & Beall, F. C., 2004. 13 Managing for Fire in the Interface: Challenges and Opportunities. Forests at the wildland-urban interface: Conservation and management, 201.
[7] Tang, Y., Bi, W., Varga, L., Dolan, T., & Li, Q., 2022. An integrated framework for managing fire resilience of metro station system: Identification, assessment, and optimization. International Journal of Disaster Risk Reduction, 77, 103037.
[8] Bojar, P., Woropay, M., Migawa, K., Szubartowski, M., & Muślewski, Ł., 2011. Transport rules and assessment of threats connected with transport of hazardous materials by train. Journal of KONES, 18, 37-43.
[9] Golwalkar, K. R., & Kumar, R., 2022. Piping Design and Pumping Systems. In Practical Guidelines for the Chemical Industry: Operation, Processes, and Sustainability in Modern Facilities (pp. 81-130). Cham: Springer International Publishing.
[10] Schmidt, M. S., 2017. Atmospheric tank failures: Mechanisms and an unexpected case study. Process safety progress, 36(4), 353-361.
[11] Purschwitz, M. A., 2006. Personal protective equipment and safety engineering of machinery. Agricultural Medicine: A Practical Guide, 53-69.
[12] Glock, C. H., Grosse, E. H., Neumann, W. P., & Feldman, A., 2021. Assistive devices for manual materials handling in warehouses: a systematic literature review. International Journal of Production Research, 59(11), 3446-3469.
[13] Ferguson, L. H., & Janicak, C. A. D. (2005). Fundamentals of fire protection for the safety professional. Government Institutes.
[14] Jones, M. R. (2019). Personal protective equipment (PPE): Practical and theoretical considerations. In Chemical Warfare Agents (pp. 303-372). CRC Press.
[15] Corbett, G. P. (2009). Fire engineering's handbook for firefighter I and II. Fire Engineering Books.
[16] Liang, Y., Zhao, C. Z., Yuan, H., Chen, Y., Zhang, W., Huang, J. Q., ... & Zhang, Q. (2019). A review of rechargeable batteries for portable electronic devices. InfoMat, 1(1), 6-32.
[17] Marcinek, M., & Marková, I. (2014). Working effectiveness of hydraulic rescue equipments for firefighters. Advanced materials research, 1001, 517-525.
[18] Meteňko, J., & Marcinek, M. (2018). Hydraulic rescue equipment for firefighters. Prace Naukowe Akademii im. Jana Długosza w Częstochowie. Technika, Informatyka, Inżynieria Bezpieczeństwa, 6.
[19] Marcinek, M. (2013). Working Time Effectiveness of Hydraulic Rescue Equipment for Firefighters. Internal Security, 5(2), 221.
[20] Horváth, L. (2022). Examination of the Application of Currently Used, New or Additional Firefighting Personal Protective Equipment. AARMS–Academic and Applied Research in Military and Public Management Science, 21(3), 49-70.
[21] Morris, B. A., 2022. The science and technology of flexible packaging: multilayer films from resin and process to end use. William Andrew.
[22] Shrestha, R., Ban, S., Devkota, S., Sharma, S., Joshi, R., Tiwari, A. P., ... & Joshi, M. K., 2021. Technological trends in heavy metals removal from industrial wastewater: A review. Journal of Environmental Chemical Engineering, 9(4), 105688.
[23] Liu, Y., Tang, X., Zeng, Q., Liu, B., Lai, J., Jin, J., & Li, S., 2024. Experimental and theoretical study on corrosion mechanism of aluminium alloy in different corrosive solutions. Journal of Molecular Liquids, 412, 125894.