



Demand Surge and Replenishment Performance of a Fuel Distribution Network During a Mass Gathering: An Industrial Engineering Analysis of the Arbaeen Pilgrimage in Karbala, Iraq

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Abstract

Large religious gatherings load regional infrastructure heavily for a short time. The load is predictable, yet how the systems that carry it actually behave is still poorly documented. This study uses the complete daily operating record of the Karbala fuel distribution branch over twenty-one consecutive days, 16 July to 5 August 2026, spanning the build-up, the Arbaeen day itself on 4 August and the first day of the return. The records cover 53 supply nodes and four petroleum products, and give for every node and day the closing stock, the volume sold, the quantity received and the orders placed. Surge factor, order fill rate, days of supply and demand amplification indicators show that system-wide days-of-supply fell to a low of 0.78 day at the peak of the load – with product-level cover as low as 0.60 day for gas oil – before recovering to 1.47 days on the Arbaeen day: the replenishment effort culminated after the demand it was meant to serve. Fitting the build-up trend and projecting it to the Arbaeen day, the usual procedure when the peak is not observed, overstates the measured requirement by 70.4% (95% prediction interval 4.45–5.48 million litres against 2.92 million actually recorded).

Keywords: Bullwhip effect; Days of supply; Fuel supply chain; Mass gathering logistics; Order fill rate

1. Introduction

Arbaeen pilgrimage to Karbala is one of the biggest mass pilgrimages repeated anywhere in the world. In approximately two weeks, the resident population of a middle-sized governorate in Iraq can be multiplied by several factors and the physical systems supporting the population (water, electricity, waste, transport and fuel) are expected to face loads that they were not designed for. The event is unique in one aspect compared to a natural disaster: It does not occur at a random time and has size that can be estimated well in advance. The issue is not, therefore, predicting; it is sizing, positioning and refilling up against a known and steep demand ramp.

The event runs on fuel. The buses and private cars which transport pilgrims to the governorate are run by gasoline. Gas oil is used to power the heavy transport fleet – and more importantly the diesel generators to power service camps, the field kitchens and the lights along the walking routes. In the same camps, kerosene is used to cook. When any one of these flows is interrupted, it rapidly becomes a drop in service to a very large number of people. Station level storage is in hours, not weeks, and there is very little built-in redundancy for failure in replenishment.



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The industrial engineering literature already holds most of the tools this problem needs. The amplification of order variability along a supply chain has been discussed since Forrester [1] and was later formalised by Lee et al. [2] and Chen et al. [3], and re-examined empirically across industries by Cachon et al. [11]. Fuel is a textbook functional product in Fisher's [10] sense – predictable, low-margin and demand-driven rather than supply-driven – which is precisely why a departure from smooth replenishment during a known event is diagnostic rather than routine. Fill rate and days of supply are standard service and cover measures in inventory and production management [4,5], with the underlying inventory theory laid out by Zipkin [12] and the wider logistics-management literature reviewed by Sheffi [13] and Ballou [14]. Work on humanitarian and disaster logistics has carried these ideas into settings with sudden, non-stationary demand [6,7], and resilience frameworks more broadly [13]. Studies of mass gatherings, on the other hand, deal almost entirely with public health and crowd safety [8,9]; the supply chain side of such events has received little attention, and even less of it based on field records rather than simulation.

The contribution made here is empirical. We use the daily reports that the Karbala branch itself produced through the whole 2026 cycle, rebuild from them a complete node-by-day dataset, and assess the performance of the network with conventional indicators. Because the record covers the pilgrimage day and not only the approach to it, four questions can be answered that are usually left open: how large the surge is and how it is distributed across products; how the replenishment system performs under it; how demand is spread over the outlets; and, the point that turns out to matter most, when the load on the distribution system actually peaks relative to the event itself.

2. Materials and Methods

2.1. The paper should have the following structure

The Karbala branch is operating in two stages. The top level is the local refinery and depot which rely on crude and finished products from the national network and provide strategic storage for the governorate. The lower echelon is made up of 53 registered supply nodes, eight of them being governmental nodes and the others being privately operated nodes and distribution squares. Product is moved by road tanker from the depot to the outlets, and the volume moved each day is recorded per product and per outlet on the daily report. There are four products processed – regular gasoline, premium (improved) gasoline, gas oil and kerosene. Liquefied petroleum gas and fuel oil are not included here and are reported separately.

Replenishment is in principle a pull system. The order for each outlet is made on a daily basis and is expressed as the number of nominally 36,000 litre loads of tanker. The branch then allocates the product available to these orders and quantity delivered will show in the report as quantity received. The size of the rationing when supply is binding is directly indicated by the difference between what was ordered and what was received. Next to each order the report also prints the corresponding number of nominal loads; this is arithmetically derived from the ordered quantity and therefore cannot be considered as an independent record of vehicle movements. We consider it to be a statement of demand on the fleet – and measure the delivered workload separately, from the receipts themselves. Governmental and private outlets are administratively distinct but are not assigned a formal priority ranking in the allocation process: the branch distributes the product available across the orders it receives from both groups on the same daily cycle, so the balance between the two channels observed in Section 3.4 reflects realised demand and delivery constraints rather than an explicit administrative preference.

2.2. Data

The main data consist of the branch position reports, numbers 198 to 218 [15], which run from 16 July to 5 August 2026 without any interruption, that is 21 observation days. Each report is a matrix of 53 rows and four products and five fields (closing stock, sales, receipts, orders and ordered loads), therefore the number of raw values is 22,260, from which 1,113 node-rows were reconstructed and checked. The check involved adding up the records at the node level for each day and product and comparing that total to the totals provided on the original report [15]. The twenty-one days were all in agreement, and so were all four products, on stock, sales, receipts and orders, thus making it possible to avoid interpolation or estimation. All quantities are in litres. An anonymised, node-level version of the reconstructed dataset can be made available as supplementary material, subject to clearance from the Ministry of Oil, to support independent verification.

The reference date is 4 August 2026, which corresponds to 20 Safar 1448 AH. The window therefore runs from D-19 to D+1 and contains the build-up, the pilgrimage day and the beginning of the return movement. Because the peak of the event lies inside the window rather than beyond it, the capacity requirement is measured directly instead of being inferred from a trend.

2.3. Performance indicators

Let $D\{p,t\}$ be the sales of product p on day t , $R\{p,t\}$ the receipts, $I\{p,t\}$ the closing stock and $O\{p,t\}$ the ordered quantity, and let $q_n = 36,000$ L be the nominal tanker load. The indicators used are the following.

The surge factor compares the highest observed demand with demand at the start of the window and expresses the amplitude of the event:

$$SF_p = \max_i(D_{p,i}) / D_{p,t} \quad (1)$$

The order fill rate gives the share of requested replenishment that the upper echelon was able to deliver. It is the main internal service measure of the chain:

$$FR_{p,t} = R_{p,t} / O_{p,t} \quad (2)$$

Days of supply expresses closing stock as a multiple of current daily consumption and is the natural robustness measure for the outlet network:

$$DOS_{p,t} = I_{p,t} / D_{p,t} \quad (3)$$

The demand amplification ratio is the empirical form of the bullwhip measure of Chen et al. [3]. It compares the relative variability of the orders with that of the sales behind them. Because the coefficient of variation depends only on the mean and the standard deviation of each series, it requires no assumption about the temporal ordering of the observations; the uncertainty of B_p was assessed separately with a 5,000-replicate day-level bootstrap, reported alongside the point estimates in Table 2:

$$B_p = CV(O_p) / CV(D_p) \quad (4)$$

The workload actually placed on the tanker fleet is expressed in nominal loads. This converts a volume into a number of vehicle movements and makes the delivery effort comparable from day to day:

$$L_t = R_t / q_n, \quad q_n = 36,000 \text{ L} \quad (5)$$

Required fleet capacity on day t is defined here as $C_{req,t} = O_t / q_n$, the number of nominal loads implied by the total orders placed that day, compared against the loads actually delivered, L_t (Eq. 5). This converts “capacity” from a descriptive term into a measured quantity: the largest single-day gap over the window occurred on 25 July, when orders implied a requirement of 137 nominal loads against 109 delivered, a shortfall of 28 loads (20.4%), indicating that on the heaviest ordering day the binding constraint was fleet and allocation capacity rather than the volume held in strategic storage.

The spatial concentration of demand over the n active outlets was measured with the Gini index of total sales per outlet across the window, together with the cumulative shares of the largest outlets in the Pareto sense:

$$G = [n + 1 - 2 \sum_i (n + 1 - i)x_i / \sum_i x_i] / n, \quad x_1 \leq x_2 \leq \dots \leq x_n \quad (6)$$

The build-up trend was described by linear regression of daily sales on time over the monotone part of the approach, 16 to 27 July, with significance judged at the 5% level. The same regression is projected forward to the Arbaeen day so that the projection can be compared with the volume actually recorded on it.

3. Results and Discussion

3.1. Magnitude, structure and timing of the demand surge

Daily behaviour of the system is summarised in Table 1. Total throughput rose from 2.90 million litres on 16 July to 3.94 million litres on 26 July, a surge factor of 1.36, and over the approach (16–27 July, $n = 12$) the linear trend is significant: $\text{sales}(t) = 2,732 + 117.7 \cdot t$ (thousand L; $\text{SE}_{\text{slope}} = 12.6$, $\text{SE}_{\text{intercept}} = 82.0$; $R^2 = 0.897$; $F(1,10) = 86.8$, $p = 3.0 \times 10^{-6}$). What the extended window adds is the shape after that point. Demand did not carry on upward to the pilgrimage. It fell away over the following week, and on 4 August the branch sold 2.92 million litres, 26.0% below the peak and only marginally above the 16 July baseline. The heaviest day for the distribution system came nine days before the day the system exists to serve.

Table 1: Daily system performance of the Karbala fuel distribution network, 16 July – 5 August 2026 (volumes in 10^3 L; loads are receipts expressed in nominal 36,000-litre tanker loads)

Date	D-day	Sales	Receipts	Stock	Orders	Fill rate	DOS (d)	Loads
16 Jul	-19	2,901	2,811	3,068	3,417	0.82	1.06	78
17 Jul	-18	2,657	2,802	3,229	3,633	0.77	1.22	78
18 Jul	-17	2,744	2,892	3,369	3,700	0.78	1.23	80
19 Jul	-16	3,121	3,178	3,412	3,958	0.80	1.09	88
20 Jul	-15	3,170	3,650	3,902	3,922	0.93	1.23	101
21 Jul	-14	3,472	3,066	3,472	4,219	0.73	1.00	85
22 Jul	-13	3,520	3,608	3,554	4,223	0.85	1.01	100
23 Jul	-12	3,750	3,262	3,087	4,325	0.75	0.82	91
24 Jul	-11	3,604	3,389	2,909	4,642	0.73	0.81	94
25 Jul	-10	3,829	3,934	3,039	4,902	0.80	0.79	109
26 Jul	-9	3,940	4,000	3,076	4,767	0.84	0.78	111
27 Jul	-8	3,838	4,107	3,229	4,692	0.88	0.84	114
28 Jul	-7	3,733	3,683	3,344	4,620	0.80	0.90	102
29 Jul	-6	3,380	3,670	3,602	4,417	0.83	1.07	102
30 Jul	-5	2,995	2,767	3,273	4,332	0.64	1.09	77
31 Jul	-4	3,149	3,298	3,374	4,021	0.82	1.07	92
1 Aug	-3	2,959	2,560	3,395	4,193	0.61	1.15	71
2 Aug	-2	3,084	3,314	3,580	3,942	0.84	1.16	92
3 Aug	-1	2,956	3,063	3,787	3,757	0.82	1.28	85
4 Aug	0	2,915	3,324	4,294	3,526	0.94	1.47	92
5 Aug	+1	2,779	2,524	4,018	3,530	0.71	1.45	70
Mean	—	3,262	3,281	3,429	4,130	0.80	1.07	91

In the background of the aggregate number there is a very product-specific pattern, as illustrated in Fig. 1 and detailed in Table 2. The absolute increases were primarily fuelled by gas oil (+58.3% from 1.26 to 2.00 million litres per day). This is similar to how generator sets and service camps are staged up in succession on the walking paths. Kerosene showed the highest relative increase at 166.5% (however, from a very low level), and it is also a camp cooking fuel, switched on late, and reached its peak on 28 July which is later than any of the other products. This is the most dramatic change of any series in the data set, with kerosene sales at 8.4 thousand litres per day on 5 August, less than a twentieth of the peak. Regular gasoline has also increased, but by a smaller value of 18.2% due to the fact that the movement of vehicles is distributed over a longer time period, and a portion of it moves to neighbouring governorates.

Premium gasoline moved against the others. It reached nearly 195 thousand litres per day during the first week, dipped to 107 thousand on 1 August and finally recovered to 196 thousand on 5 August. The premium decline does not necessarily indicate less mobility, as total gasoline use increased during the same period. The branch changed the tanker and product from premium grade to regular grade when the pressure was felt and to the premium grade again when the pressure was eased. Premium stock built up in the interim and its cover has been maintained at a level above 3 days. The mechanism is simply a

product-mix rationing policy, albeit a hidden one, and the clean reversal after the event is what makes it a policy and not a demand effect.

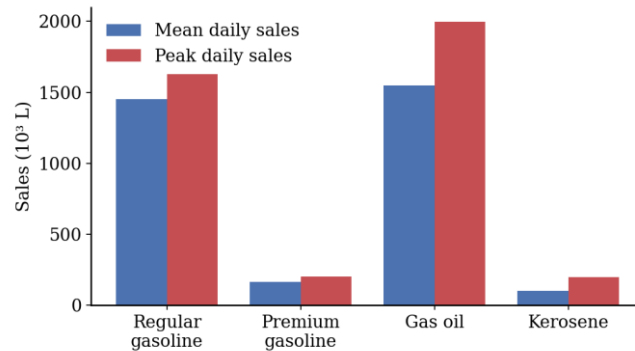


Fig. 1: Mean and peak daily sales by product over the observation window.

Table 2: Product-level performance indicators over the observation window

Indicator	Regular gasoline	Premium gasoline	Gas oil	Kerosene
Mean daily sales (10³ L)	1,450	164	1,548	100
Peak daily sales (10³ L)	1,627	204	1,997	197
Day of peak (rel. Arbaeen)	D-9	D-12	D-9	D-7
Day-1 sales (16 Jul, 10³ L)	1,376	189	1,262	74
Growth, first day to peak (%)	+18.2	+7.7	+58.3	+166.5
Change, peak to Arbaeen day (%)	-10.8	-26.8	-35.2	-89.7
Coefficient of variation	0.064	0.214	0.179	0.532
Aggregate order fill rate	0.80	0.86	0.78	0.86
Mean days of supply (d)	0.86	1.74	0.99	8.18
Minimum days of supply (d)	0.67	0.67	0.60	1.80
Amplification ratio B	1.66	1.47	0.80	1.04
95% CI for B (bootstrap)	1.14-2.22	1.00-2.11	0.55-1.11	0.65-1.45
Total sales over window (10⁶ L)	30.45	3.45	32.51	2.09
Total receipts over window (10⁶ L)	30.50	3.50	32.97	1.93
Load-equivalents delivered	847	97	916	54

3.2. Replenishment performance and rationing

Over the whole window receipts almost exactly matched sales: 68.90 against 68.50 million litres, a replenishment ratio of 1.006. This is confirmed by a system-wide mass-balance check, $I_1 + \Sigma R = \Sigma D + I_T$ (opening stock plus total receipts against total sales plus closing stock), computed separately for each product: the balance closes to within 0.6% of total sales for every product (gas oil -0.6%, regular gasoline +0.1%, premium +0.4%, kerosene -0.1%), so the near-unity ratio reflects a genuine system-wide balance and not an accounting artefact. The branch as a whole neither built up nor drew down any real buffer across the cycle. That finding matters on its own. The system entered the most demanding week of its year hand to mouth, replacing what it sold and little more, with no pre-event stock at all. This system-wide balance is aggregate, however: individual outlets ran surplus or deficit throughout the window (Sections 3.3–3.4), so a balanced governorate-level ratio is compatible with real, and uneven, station-level shortage. When the load is known months in advance, this is exactly the situation that pre-positioning exists to prevent.

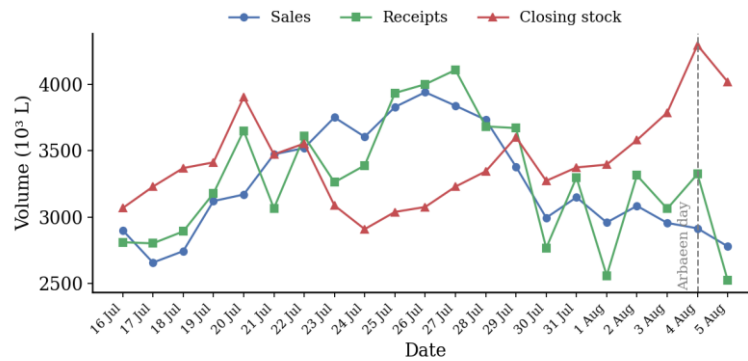


Fig. 2: Daily sales, receipts and closing stock, system-wide, 16 July – 5 August 2026. The broken line marks the Arbäeen day.

The order fill rate for the system was on an average 0.80 (95% bootstrap CI 0.77–0.83) and no day had an order fill rate of one, its highest was 0.94 on Arbäeen day itself, but orders were already down. For gas oil the aggregate value was 0.79 (95% CI 0.74–0.84), which means that close to a quarter of the volume requested for the most critical product was not delivered on the day it was requested. The two lowest daily values (on 30 July and 1 August) occurred in the week following the demand peak, when the branch was replenishing stock, and not during a period of increasing load. A low fill rate allows two interpretations: that there really is a constraint on supply from upstream sources, or that outlets are inflating their orders in anticipation of rationing; this reading is inferred from the aggregate indicators available here and would be strengthened by outlet-level allocation records not included in the daily reports. As can be seen from Section 3.5, the evidence available supports the first reading for gas oil and the second reading for gasoline.

The incidence of zero replenishment provides a complementary view. Thirty-one percent (31.0%) of the station-days with gas oil sales received no delivery at all, and for regular gasoline the figure was 26.9% of the station-days with sales. The percentages for kerosene and premium gasoline were 65.0% and 57.4%, respectively, reflecting the length and lumpiness of delivery cycles for these two products.

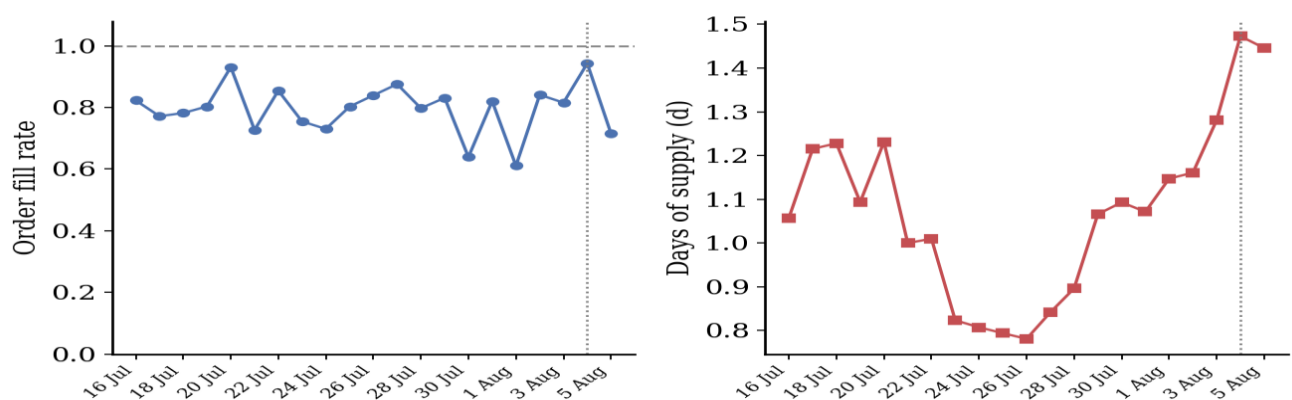


Fig. 3: Order fill rate (left) and days of supply (right), system-wide, 16 July – 5 August 2026. The dotted line marks the Arbäeen day.

3.3. Inventory cover and outlet-level stockout risk

On 16 July there were 1.06 days of system cover but on 26 July there were only 0.78 days, so at the peak of the load the entire system was carrying less than one day's use. The lowest values were 0.60 days for gas oil and 0.67 days for regular gasoline. A tanker cycle from the depot to the outlet and back again requires several hours and a cover of about two thirds of a day provides virtually no protection in the

event of a single day's disconnection from the source. The cover then slowly and gradually increased and reached 1.47 days on Arbaeen day, the best of the window.

At node level the situation at the peak is worse than the aggregate number indicates, since stock is not equally distributed. The median number of days of cover for regular gasoline and gas oil was 0.65 and 0.69, respectively, with 39.4% and 37.1% of outlets having less than half a day of cover, respectively, and approximately two-thirds having less than a day. In total, the percentage of outlet-days below half a day increased from 23.2% at the beginning of the window to 38.2% on 26 July, dropping back to 13.2% on Arbaeen day. The low-cover episodes documented here are consistent with allocation and scheduling constraints within the last echelon, and they belong to the approach week rather than to the pilgrimage day; confirming that stockouts translated directly into station queues would require dispatch or customer-facing records not available in the daily position reports used here.

3.4. Spatial concentration of demand

Sales were recorded at 38 of the 53 nodes, and the rest were mostly distribution squares, which were not active during this period. The amount of demand is heavily concentrated among the active nodes. The Gini index for total sales is 0.416 for the network, and 0.477 for gas oil. As shown in the Lorenz curves in Fig. 4, the 5 largest outlets accounted for 37.5% of all sales, and 52.4% of gas oil sales, and the largest quintile of outlets for almost half of all sales.

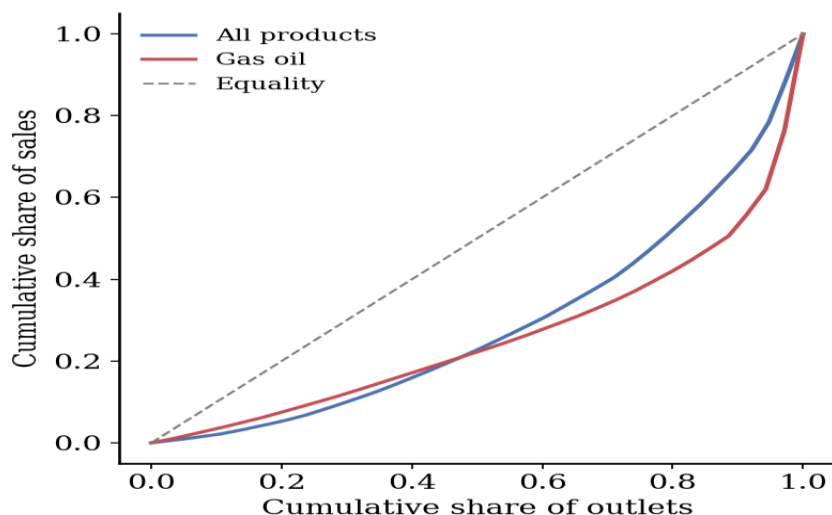


Fig. 4: Lorenz curves of outlet-level sales concentration, all products and gas oil, 16 July – 5 August 2026.

This concentration is structural, not accidental. One governmental gas oil station handled 7.69 million litres over the window and a second station 4.65 million; between them these two nodes carried 38.0% of all the gas oil and 18.0% of everything the branch delivered. Growth was just as uneven. Comparing the first three reporting days with the three days around the peak, the median outlet increased its gas oil sales by 21.5%, the upper quartile by more than 74.9% and the most exposed node by 327%, while a few peripheral outlets contracted. A replenishment policy that allocated tanker capacity uniformly, or in proportion to historical shares, would therefore serve the network badly. What is needed is a differentiated policy, with dedicated shuttle capacity for the small number of critical nodes.

The governmental and private sub-networks also moved apart, and then moved back. The governmental share of gas oil sales rose from 47.1% at the start of the window to 53.4% at the peak, then fell to 29.8% on the Arbaeen day, while its share of regular gasoline declined steadily from 29.9% to about 15%. The governmental channel absorbed the generator and heavy transport load and the private channel absorbed

the passenger vehicle load. The two require different replenishment cadences, and the governmental one is the more sharply peaked of the two.

3.5. Demand amplification and ordering regime

The amplification ratio of Equation (4) separates the products sharply. B equals 1.66 (95% bootstrap CI 1.14–2.22) for regular gasoline and 1.47 (95% CI 1.00–2.11) for premium, so the orders placed were considerably more variable than the sales behind them. This is the classical bullwhip signature, produced here by anticipation of rationing and by the fact that orders can only be placed in whole tanker loads. For gas oil B equals 0.80 (95% CI 0.55–1.11): the orders were smoother than the sales. Such an inversion is typical of a supply-constrained regime, in which outlets order at or near an administrative ceiling whatever their sales, so that the order series flattens while the sales series keeps following the event; the overlap between the gas-oil and regular-gasoline intervals indicates that the two ratios, while pointing in opposite directions, should be read as distinguishing regimes rather than as a precisely separated pair of point estimates. The two regimes call for opposite treatments. Gasoline ordering would improve with information sharing and a move towards centrally computed allocation. Gas oil needs more physical capacity, because no amount of smoothing of information will release a constraint that is materially real.

3.6. Timing of replenishment relative to demand

Over the window the branch delivered 68.90 million litres, that is 1,914 nominal tanker loads, an average of 91 loads per day. The busiest delivery day was 27 July with 114 loads, one day after the demand peak; on the Arbaeen day the figure was 92. Demand and delivery are therefore out of phase. Between 26 July and 4 August system stock rose 39.6%, from 3.08 to 4.29 million litres, while daily sales fell 26.0%. The network finished assembling its buffer a week after the week in which the buffer was needed, and then carried it through a pilgrimage day whose fuel requirement was no greater than an ordinary July day. The cost of this does not appear in the aggregate, which stays in balance throughout; it appears in the 38.2% of outlets that were below half a day of cover on 26 July.

The observed peak also provides a direct test of the projection method that has to be used when the peak is not observed. Extrapolating the 16–27 July regression ($\text{sales}(t) = 2,732 + 117.7 \cdot t$ thousand L, $R^2 = 0.897$, $n = 12$; see Section 3.1) to 4 August gives an expected requirement of 4.97 million litres (95% prediction interval 4.45–5.48 million litres) against 2.92 million actually recorded – outside the interval – an overstatement of 70.4%. Planning on that basis would size the fleet for a day that never comes and miss the day that does. Three practical conclusions follow. Capacity should be positioned against the transport peak, roughly D–10 to D–7 in this cycle, rather than against the event date; this is a directional recommendation based on the observed timing pattern and has not been evaluated through scenario analysis or optimisation. The buffer that had accumulated by 4 August should be built a week earlier, which is a scheduling change and not an investment. And a linear projection of the approach should not be used as a planning figure for the event day in gatherings of this kind, because the approach and the day itself are governed by different mechanisms: pilgrims arrive over a fortnight by vehicle, but converge on foot at the end, when vehicle and generator demand is already falling.

The results above are discussed only against the branch's own record; no comparable fuel-supply data are publicly available for other mass religious gatherings. Hajj, the largest annual mass gathering in the world, shares the two structural features central to this study – a known date and a short, sharp demand pulse – and its transport logistics have been studied through discrete-event simulation of buses, shuttles and trains moving pilgrims between sites [16]. That literature, however, addresses the movement of pilgrims themselves rather than the fuel supply chain that underpins it; the absence of an equivalent fuel-

logistics study for Hajj is itself part of the gap this study addresses, and a direct numerical comparison of amplification or service-level indicators between the two events is not possible with data currently in the public domain.

3. Conclusion

We have treated a mass religious gathering as an industrial engineering problem of capacity and inventory, and quantified the behaviour of the Karbala fuel distribution network over twenty-one consecutive days spanning Arbaeen 2026. The main findings are the following.

First, the surge is large, structurally uneven, and it does not coincide with the event. Total throughput rose 35.8% to a peak on 26 July, nine days before the pilgrimage, with gas oil up 58.3% and kerosene up 166.5% while premium gasoline was displaced and then recovered. By the Arbaeen day itself, throughput was 26.0% below that peak. Planning on aggregate volume, or on the event date, would misallocate the fleet twice over.

Second, the replenishment system worked hand to mouth. The replenishment ratio over the window was 1.006 with no pre-positioned buffer, the aggregate order fill rate was 0.79 and never reached one on any day, and system cover fell below a single day of consumption during the approach week.

Third, the risk sits in the last echelon rather than in the aggregate. With a Gini index of 0.416, and 38.2% of active outlets holding less than half a day of cover on the busiest day, service can fail at individual stations while the governorate as a whole remains in balance.

Fourth, the ordering regime is not the same for all products: the amplification ratio is 1.66 for regular gasoline against 0.80 for gas oil, so remedies based on information and remedies based on capacity have to be applied selectively.

Fifth, replenishment lagged demand by about a week. Deliveries peaked on 27 July and stock reached its maximum on 4 August, by which time sales had already fallen back. Extrapolating the approach trend to the Arbaeen day overstates the measured requirement by 70.4%, which is a caution for any study of a mass gathering whose observation window stops short of the event.

The main limitations are that recorded sales are bounded by availability and therefore represent served rather than latent demand, so the true surge is probably understated; that the return phase is observed for one day only; and that the reported count of tanker loads is derived from orders, so fleet workload had to be reconstructed from delivered volume rather than observed directly. Further work should extend the observation window through the return, treat the depot-to-outlet system explicitly as a queueing and vehicle-routing problem, and weigh pre-positioning policies against the cost of the additional storage they require.

Acknowledgement

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