Table 1: Latency comparison of query reformulation methods (in seconds) over 100 queries. Values are reported with 95% confidence intervals in [·].
System specifications: CPU — Intel(R) Core(TM) i7-14700HX; GPU — NVIDIA GeForce RTX 4070 Laptop GPU; average CPU utilization during measurement: ∼5%.

Method	Latency
GQR	0.761 [0.710, 0.812]
GenQR	1.472 [1.361, 1.584]
Q2E	1.487 [1.370, 1.605]
Query2Doc	3.998 [3.753, 4.242]
GenQREnsemble	15.157 [14.613, 15.701]
EQR (k=3)	2.204 [1.897, 2.610]
EQR (k=5)	3.260 [2.833, 3.688]
EQR (k=8)	4.950 [4.538, 5.363]
EQR (k=10)	6.133 [5.600, 6.665]

Table 2: Comparison of query reformulation (QR) methods using different dense retrieval embedding models across three benchmark datasets. Results are averaged over five independent runs with the LLM (temperature = 1). Best-performing results are highlighted in bold. Statistically significant improvements over the strongest baseline (paired t-test, $p < 0.05$) are marked with an asterisk. **EQR** consistently and significantly outperforms other LLM-based QR methods across all datasets and embedding models.

	TravelDest				TripAdvisor Hotel				Yelp Restaurant			
	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30
all-MiniLM-L6-v2												
No QR	0.565	0.506	0.548	0.476	0.259	0.306	0.205	0.154	0.473	0.437	0.455	0.381
GQR	0.588	0.531	0.573	0.492	0.305	0.341	0.244	0.170	0.521	0.472	0.500	0.415
GenQR	0.615	0.549	0.590	0.509	0.349	0.369	0.284	0.172	0.574	0.511	0.548	0.443
GenQREnsemble	0.607	0.533	0.567	0.501	0.333	0.376	0.269	0.169	0.561	0.503	0.538	0.425
Q2E	0.627	0.532	0.603	0.514	0.325	0.374	0.259	0.172	0.573	0.508	0.547	0.419
Query2Doc	0.673	0.554	0.640	0.510	0.288	0.343	0.218	0.164	0.424	0.385	0.402	0.347
EQR (Ours)	**0.720***	**0.620***	**0.677***	**0.563***	**0.369***	**0.408***	**0.295***	**0.185***	**0.616***	**0.536***	**0.583***	**0.466***
e5-small-v2												
No QR	0.578	0.522	0.564	0.491	0.269	0.314	0.216	0.152	0.577	0.505	0.545	0.427
GQR	0.632	0.557	0.614	0.516	0.293	0.347	0.226	0.168	0.602	0.534	0.567	0.443
GenQR	0.686	0.592	0.659	0.539	0.321	0.375	0.245	0.174	0.636	0.553	0.597	0.466
GenQREnsemble	0.661	0.590	0.641	0.516	0.337	0.368	0.250	0.159	0.629	0.545	0.570	0.471
Q2E	0.655	0.546	0.634	0.521	0.325	0.380	0.257	0.173	0.616	0.546	0.570	0.468
Query2Doc	0.692	0.579	0.647	0.514	0.282	0.340	0.224	0.166	0.525	0.470	0.500	0.416
EQR (Ours)	**0.721***	**0.613***	**0.690***	**0.558***	**0.358***	**0.398***	**0.273***	**0.178**	**0.656***	**0.571***	**0.618***	**0.491***

Table 3: Run 1 Results

	TravelDest				TripAdvisor Hotel				Yelp Restaurant			
	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30
all-MiniLM-L6-v2												
No QR	0.564	0.503	0.549	0.473	0.255	0.304	0.207	0.151	0.474	0.435	0.455	0.385
GQR	0.578	0.537	0.571	0.479	0.292	0.329	0.256	0.170	0.526	0.477	0.497	0.419
GenQR	0.612	0.546	0.590	0.510	0.346	0.370	0.282	0.173	0.573	0.510	0.550	0.443
GenQREnsemble	0.608	0.536	0.565	0.501	0.336	0.380	0.269	0.171	0.559	0.505	0.536	0.425
Q2E	0.628	0.532	0.605	0.512	0.327	0.377	0.261	0.172	0.572	0.507	0.547	0.422
Query2Doc	0.672	0.553	0.642	0.509	0.288	0.344	0.218	0.166	0.422	0.385	0.404	0.345
EQR (Ours)	**0.719**	**0.618**	**0.679**	**0.563**	**0.371**	**0.404**	**0.296**	**0.185**	**0.619**	**0.538**	**0.584**	**0.465**
e5-small-v2												
No QR	0.579	0.523	0.565	0.494	0.272	0.313	0.216	0.151	0.580	0.503	0.546	0.428
GQR	0.622	0.556	0.615	0.521	0.285	0.353	0.236	0.153	0.618	0.517	0.567	0.436
GenQR	0.685	0.592	0.658	0.538	0.322	0.375	0.245	0.174	0.635	0.552	0.595	0.465
GenQREnsemble	0.662	0.589	0.642	0.515	0.338	0.368	0.252	0.162	0.628	0.548	0.572	0.472
Q2E	0.655	0.548	0.636	0.519	0.324	0.379	0.259	0.172	0.616	0.543	0.572	0.471
Query2Doc	0.691	0.582	0.644	0.518	0.284	0.342	0.225	0.166	0.525	0.472	0.500	0.415
EQR (Ours)	**0.721**	**0.613**	**0.690**	**0.559**	**0.358**	**0.397**	**0.273**	**0.180**	**0.657**	**0.572**	**0.618**	**0.493**

Table 4: Run 2 Results

	TravelDest				TripAdvisor Hotel				Yelp Restaurant			
	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30
all-MiniLM-L6-v2												
No QR	0.568	0.505	0.544	0.472	0.263	0.311	0.201	0.153	0.469	0.441	0.448	0.377
GQR	0.589	0.531	0.575	0.489	0.308	0.348	0.235	0.163	0.521	0.478	0.492	0.406
GenQR	0.607	0.553	0.586	0.513	0.351	0.370	0.282	0.170	0.578	0.515	0.546	0.438
GenQREnsemble	0.602	0.530	0.569	0.501	0.333	0.375	0.264	0.168	0.566	0.505	0.534	0.425
Q2E	0.622	0.525	0.604	0.519	0.326	0.370	0.255	0.172	0.576	0.512	0.545	0.416
Query2Doc	0.671	0.555	0.641	0.511	0.288	0.346	0.215	0.168	0.426	0.382	0.403	0.352
EQR (Ours)	**0.720**	**0.625**	**0.679**	**0.559**	**0.378**	**0.411**	**0.289**	**0.180**	**0.614**	**0.536**	**0.588**	**0.469**
e5-small-v2												
No QR	0.574	0.518	0.569	0.490	0.269	0.307	0.214	0.153	0.578	0.509	0.539	0.422
GQR	0.629	0.549	0.616	0.519	0.289	0.332	0.217	0.175	0.598	0.543	0.562	0.439
GenQR	0.684	0.595	0.664	0.544	0.325	0.370	0.238	0.174	0.639	0.557	0.596	0.467
GenQREnsemble	0.660	0.586	0.643	0.517	0.332	0.369	0.249	0.157	0.635	0.541	0.573	0.473
Q2E	0.661	0.543	0.638	0.525	0.331	0.385	0.261	0.167	0.614	0.550	0.566	0.465
Query2Doc	0.695	0.577	0.651	0.511	0.287	0.342	0.230	0.167	0.527	0.469	0.499	0.414
EQR (Ours)	**0.722**	**0.611**	**0.697**	**0.558**	**0.352**	**0.403**	**0.278**	**0.180**	**0.661**	**0.569**	**0.616**	**0.488**

Table 5: Run 3 Results

	TravelDest				TripAdvisor Hotel				Yelp Restaurant			
	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30
all-MiniLM-L6-v2												
No QR	0.562	0.505	0.547	0.480	0.261	0.309	0.209	0.150	0.471	0.438	0.462	0.382
GQR	0.586	0.530	0.579	0.494	0.307	0.345	0.235	0.167	0.532	0.465	0.514	0.420
GenQR	0.620	0.545	0.592	0.515	0.348	0.374	0.284	0.171	0.577	0.514	0.551	0.445
GenQREnsemble	0.613	0.528	0.571	0.496	0.333	0.374	0.268	0.165	0.555	0.501	0.540	0.423
Q2E	0.628	0.535	0.602	0.519	0.323	0.372	0.255	0.176	0.567	0.500	0.548	0.419
Query2Doc	0.675	0.552	0.641	0.511	0.295	0.339	0.224	0.161	0.426	0.384	0.407	0.337
EQR (Ours)	**0.713**	**0.616**	**0.677**	**0.563**	**0.369**	**0.411**	**0.304**	**0.191**	**0.615**	**0.539**	**0.589**	**0.471**
e5-small-v2												
No QR	0.585	0.523	0.567	0.494	0.274	0.319	0.219	0.152	0.578	0.509	0.541	0.421
GQR	0.644	0.563	0.624	0.518	0.285	0.342	0.233	0.173	0.604	0.540	0.576	0.448
GenQR	0.691	0.587	0.658	0.540	0.320	0.368	0.241	0.173	0.633	0.559	0.599	0.463
GenQREnsemble	0.660	0.591	0.640	0.510	0.338	0.368	0.248	0.161	0.627	0.542	0.568	0.465
Q2E	0.658	0.544	0.630	0.515	0.326	0.379	0.252	0.178	0.621	0.549	0.564	0.464
Query2Doc	0.684	0.580	0.650	0.514	0.283	0.339	0.230	0.160	0.530	0.479	0.499	0.421
EQR (Ours)	**0.727**	**0.609**	**0.688**	**0.560**	**0.361**	**0.397**	**0.275**	**0.181**	**0.650**	**0.568**	**0.620**	**0.487**

Table 6: Run 4 Results

	TravelDest				TripAdvisor Hotel				Yelp Restaurant			
	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30
all-MiniLM-L6-v2												
No QR	0.558	0.510	0.554	0.480	0.262	0.307	0.202	0.158	0.480	0.437	0.453	0.381
GQR	0.582	0.536	0.571	0.498	0.307	0.348	0.242	0.168	0.512	0.470	0.490	0.405
GenQR	0.617	0.547	0.593	0.504	0.347	0.366	0.288	0.166	0.569	0.505	0.546	0.443
GenQREnsemble	0.603	0.529	0.570	0.508	0.333	0.376	0.277	0.168	0.559	0.501	0.536	0.421
Q2E	0.632	0.529	0.598	0.505	0.326	0.373	0.266	0.167	0.575	0.514	0.546	0.416
Query2Doc	0.674	0.556	0.635	0.505	0.283	0.339	0.211	0.160	0.418	0.383	0.397	0.352
EQR (Ours)	**0.726**	**0.626**	**0.672**	**0.571**	**0.363**	**0.406**	**0.297**	**0.189**	**0.618**	**0.532**	**0.578**	**0.467**
e5-small-v2												
No QR	0.577	0.530	0.562	0.489	0.265	0.313	0.216	0.148	0.576	0.498	0.552	0.427
GQR	0.633	0.558	0.607	0.511	0.303	0.355	0.221	0.168	0.596	0.535	0.565	0.445
GenQR	0.693	0.592	0.663	0.530	0.319	0.382	0.249	**0.176**	0.642	0.549	0.602	0.464
GenQREnsemble	0.656	0.592	0.639	0.519	0.333	0.362	0.247	0.159	0.631	0.549	0.566	0.471
Q2E	0.650	0.542	0.636	0.525	0.321	0.372	0.254	0.169	0.614	0.548	0.572	0.469
Query2Doc	0.694	0.576	0.637	0.511	0.278	0.341	0.218	0.173	0.522	0.466	0.495	0.413
EQR (Ours)	**0.716**	**0.612**	**0.691**	**0.560**	**0.358**	**0.401**	**0.268**	0.174	**0.656**	**0.573**	**0.623**	**0.491**

Table 7: Run 5 Results

	TravelDest				TripAdvisor Hotel				Yelp Restaurant			
	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30	NDCG@10	NDCG@30	P@10	P@30
all-MiniLM-L6-v2												
No QR	0.571	0.506	0.548	0.474	0.254	0.298	0.205	0.158	0.469	0.433	0.455	0.378
GQR	0.604	0.520	0.571	0.498	0.312	0.337	0.251	**0.180**	0.511	0.472	0.507	0.424
GenQR	0.619	0.552	0.590	0.504	0.353	0.366	0.285	0.179	0.572	0.513	0.547	0.447
GenQREnsemble	0.609	0.544	0.562	0.498	0.329	0.374	0.265	0.172	0.567	0.503	0.542	0.432
Q2E	0.624	0.538	0.604	0.517	0.323	0.378	0.260	0.171	0.575	0.505	0.550	0.420
Query2Doc	0.675	0.553	0.641	0.514	0.284	0.349	0.220	0.165	0.429	0.391	0.397	0.351
EQR (Ours)	**0.723**	**0.613**	**0.676**	**0.558**	**0.365**	**0.407**	**0.291**	0.180	**0.612**	**0.533**	**0.577**	**0.460**
e5-small-v2												
No QR	0.575	0.518	0.558	0.489	0.265	0.319	0.215	0.158	0.574	0.508	0.547	0.435
GQR	0.633	0.558	0.607	0.511	0.303	0.355	0.221	0.168	0.596	0.535	0.565	0.445
GenQR	0.677	0.592	0.653	0.544	0.319	0.382	0.252	0.175	0.631	0.548	0.595	0.470
GenQREnsemble	0.665	0.594	0.642	0.517	0.342	0.373	0.252	0.156	0.624	0.546	0.572	0.472
Q2E	0.650	0.551	0.631	0.522	0.325	0.385	0.261	**0.179**	0.613	0.538	0.576	0.472
Query2Doc	0.697	0.582	0.651	0.515	0.279	0.334	0.219	0.164	0.523	0.466	0.507	0.416
EQR (Ours)	**0.721**	**0.620**	**0.684**	**0.554**	**0.363**	**0.392**	**0.271**	0.176	**0.657**	**0.574**	**0.612**	**0.494**