

MAINS MASTERY 2026 · GS PAPER I · QUESTION 4 · STUDENT EDITION

The Fujiwhara Effect and Tropical Cyclones

THE QUESTION, AS SET IN UPSC CSE MAINS 2026

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

Directive: What, Explain | 10 marks | 150 words | Geography: climatology

1 **PYQ Deep Decode**
Demand, hidden demand, structure, form

2 **PYQ Intelligence**
2013 to 2026: cyclones and warnings

3 **Additional information**
Mechanism, outcomes, examples

4 **Pitfalls and variations**
Corrections and changed directives

5 **The model answer**
One answer, a flow and points

6 **Other ways to write it**
Outlines, and when each works

7 **Quick recall**
Sixteen facts for Mains and Prelims

8 **Write it yourself**
A seven-point self-check

1921
Sakuhei Fujiwhara's paper

~1,400 km
distance at which interaction becomes noticeable

3
outcomes: orbit and escape, merger, straining-out

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What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

1 PYQ Deep Decode

Read the question the way the examiner set it: the demand, the hidden demand, the structure that follows from both, and how the answer should be presented, opened and closed.

1.1 The demand

Two clear tasks. First, say **what the Fujiwhara effect is**: a definition with its mechanism. Second, **explain its impact** on two things the question names separately: the **movement** (track) and the **intensity** of tropical cyclones. An answer that only defines, or that mixes track and intensity into one paragraph, leaves marks on the table.

Words in the question	What they ask you to do	What goes wrong if you miss them
What is	Define it precisely: two cyclonic vortices close enough to **rotate around a common centre**; name Sakuhei Fujiwhara (1921).	A vague "when two cyclones meet".
the Fujiwhara effect	Give the conditions: distance (interaction noticeable within about **1,400 km**), direction (anticlockwise in the Northern Hemisphere).	No numbers, no mechanism.
Explain its impact on the movement	Track changes: mutual orbit, deflection, loops, stalling, sudden turns.	Ignoring track effects.
and intensity	Strength changes are varied: merger can enlarge or reorganise a storm; deformation, shear or disrupted moisture can weaken one; sometimes a storm re-intensifies. Dominating the interaction is not the same as gaining strength.	Assuming both always weaken or the stronger always strengthens.
of tropical cyclones	Use real examples: Parma and Melor (2009), Hilary and Irwin (2017) for track; Seroja and Odette (2021) for intensity.	A theory answer with no evidence.

THE DEMAND IN ONE LINE

Define the Fujiwhara effect with its mechanism and thresholds, then explain separately how it changes the tracks and the intensities of interacting tropical cyclones, with examples.

1.2 The hidden demand

The effect has **no single outcome**. Depending on the two storms' relative size, strength and distance, they may orbit and separate, the larger may absorb the smaller, or the smaller may be torn apart. That variety is exactly why the effect matters for **forecasting and disaster preparedness**: tracks become erratic and landfall harder to predict. A strong answer ends there, with what it means for early warning, including in India's cyclone management.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

Each point should name the effect, explain the mechanism, and give an example. The last column is where the hidden demand begins.

Impact	Mechanism and example	Why it matters
Movement	Mutual orbit; Typhoon Parma looped and lingered near the Philippines as Melor approached (2009).	Longer rain over one area; harder track forecasts.
Intensity	Odette circled Seroja and dissipated, while changed moisture and shear helped Seroja re-intensify before its Western Australian landfall (April 2021).	Unequal outcomes; warnings must adapt.

WEAK

The Fujiwhara effect is when two cyclones come together and dance around each other, which changes their path and strength.

STRONG

When two tropical cyclones approach within roughly 1,400 km, their circulations may begin to interact; stronger interaction can produce mutual orbiting, track deflection, merger or disruption of the weaker vortex, and intensity changes vary, making forecasts harder.

1.3 The structure

The question has **two explicit demands** (what it is; its impact), and the impact has two parts the question names (movement, intensity). So a useful answer has **three short parts**, with the hidden demand in the conclusion. The shares are of the body between the introduction and the conclusion; they are a teaching guide, not a UPSC rule.

Introduction	1. Mechanism about one-quarter	2. Movement about three-eighths	3. Intensity about three-eighths	Conclusion

Part 1 **Mechanism** **about one-quarter**

Threshold	Interaction may begin within roughly 1,400 km and strengthens as storms approach; very close approaches may allow merger or straining-out. Approximate, not universal.
Rotation	Around a common centre, anticlockwise in the Northern Hemisphere.

Parts 2 and 3 **Movement and intensity** **about three-quarters**

Movement	Orbit, deflection, loops, stalling; the smaller orbits the larger.
Intensity	Merger may enlarge or reorganise a storm without raising peak winds; deformation, shear or disrupted moisture can weaken a vortex, while a favourable environment may allow intensification.

1.4 How to present it

The form follows the question. The effect is a **spatial** process, and a small **diagram** of two vortices orbiting a common centre explains it faster than words; headed points then carry movement and intensity separately.

Form	Fit here	Reason
Diagram, then headed points	**Best**	The geometry at a glance; the two impacts kept apart.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

Form	Fit here	Reason
Outcome table	Good	Orbit, merger, straining-out side by side.
Paragraphs only	Weak	Mechanism is hard to follow in prose.

1.5 The introduction and the conclusion

The introduction serves the whole question. It defines the effect, names Fujiwhara and the year, and gives the distance at which it begins.

The conclusion settles the demand. It says why the impact matters: erratic tracks and uneven intensities demand **ensemble forecasting** and flexible warnings.

2 PYQ Intelligence 2013 to 2026

The question's context, its place in a line of GS I questions on cyclones and atmospheric circulation, and what to prepare next.

2.1 Why the subject was topical

Twin cyclones have drawn wide attention in recent seasons. UPSC never states why it sets a question, so treat this as **context, not cause**. Everything in this table predates the examination.

When	What happened	Why it matters for this question
July 2017	Eastern Pacific: **Hurricane Hilary's** stronger circulation slowed **Irwin** and turned it north-eastward; the two did not merge, and both later weakened over cooler water.	A textbook case of track alteration.
8-10 April 2021	Eastern Indian Ocean: **Odette** circled **Seroja** and dissipated; changes in moisture and shear helped Seroja re-intensify before landfall in Western Australia.	An Indian Ocean case showing both track and intensity effects.
Late September 2025	Atlantic: **Humberto** weakened the subtropical ridge steering **Imelda**, contributing to Imelda's east-north-eastward turn away from the United States: an asymmetric interaction, not a classic mutual orbit.	A recent, widely reported partial case.

2.2 The skill UPSC keeps testing

UPSC has repeatedly tested cyclone formation, naming, sea temperatures, atmospheric circulation and extreme weather. Questions are verbatim unless marked.

Year	The question as UPSC set it, or a marked summary	What it asked of you	What changed in 2026
2014 GS I	Tropical cyclones are largely confined to South China Sea, Bay of Bengal and Gulf of Mexico. Why?	Where cyclones form.	From formation to interaction.
2013 GS I	The recent cyclone on east coast of India was called 'Phailin'. How are the tropical cyclones named across the world? Elaborate.	Naming cyclones.	From naming to interaction.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

Year	The question as UPSC set it, or a marked summary	What it asked of you	What changed in 2026
2016 GS I	Discuss the concept of air mass and explain its role in macro-climatic changes.	Atmospheric circulation.	Circulation steering storms.
2022 GS I	Discuss the meaning of colour-coded weather warnings for cyclone prone areas given by India Meteorological Department.	Warnings and preparedness.	Why interacting cyclones complicate warnings.
2024 GS I	What is sea surface temperature rise? How does it affect the formation of tropical cyclones?	Ocean heat and cyclones.	The closest precedent: from formation to interaction and intensity.
2026 GS I, III	Retrospective links in the same examination: GS I Q14, "Compare the Loo, Chinook and Foehn winds with respect to their regions of prevalence, their nature and climatic impacts."; GS III Q18, "Community participation is the cornerstone of effective disaster management". Analyse this statement with suitable examples from India. Also discuss the challenges to community participation and measures to strengthen it.	Disaster management.	The human side of cyclone forecasting.

Also related, verbatim: 2013: "What do you understand by the phenomenon of 'temperature inversion' in meteorology? How does it affect weather and the habitants of the place?" 2014: "Most of the unusual climatic happenings are explained as an outcome of the El-Nino effect. Do you agree?" 2022: "Troposphere is a very significant atmospheric layer that determines weather processes. How?" 2024: "What is a twister? Why are the majority of twisters observed in areas around the Gulf of Mexico?" 2024: "What is the phenomenon of 'cloudbursts'? Explain." 2023: "Comment on the resource potentials of the long coastline of India and highlight the status of natural hazard preparedness in these areas." 2021: "Briefly mention the alignment of major mountain ranges of the world and explain their impact on local weather conditions, with examples."

CARRY THIS METHOD TO ANY "WHAT IS, EXPLAIN ITS IMPACT" QUESTION

1. **Define** with the originator and year.
2. **Give the mechanism**, with numbers.
3. **Split the impact** exactly as the question does.
4. **One example** per impact.
5. **End with significance** for India.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

2.3 What to prepare next

CYCLONE SCIENCE

Conditions for formation	Sea surface around 26.5°C or warmer through a deep upper layer (about 50 m), Coriolis force, low vertical shear, a pre-existing disturbance, moist mid-levels; a guideline, not an absolute threshold.
Steering currents	Large-scale winds that normally decide a cyclone's track.
Vertical wind shear	Change of wind with height that tilts and weakens a storm.
Rapid intensification	A rise in maximum sustained wind of at least 30 knots (about 55 km/h) in 24 hours (US National Hurricane Center definition).

INDIA

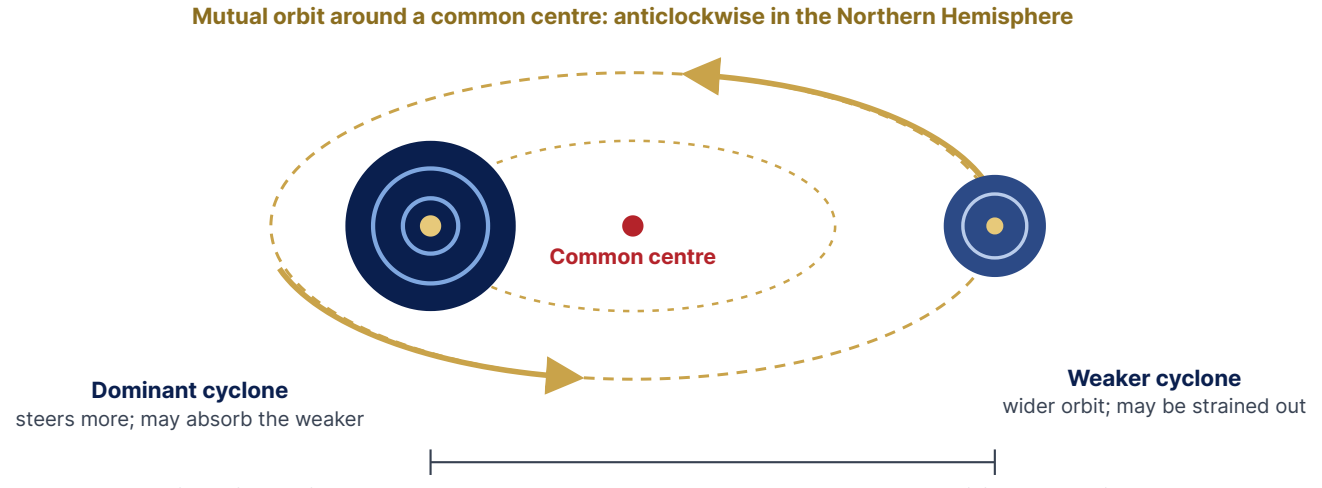
IMD and RSMC New Delhi	Regional Specialised Meteorological Centre for the North Indian Ocean.
Colour-coded warnings	Green (no warning), yellow (watch), orange (be prepared), red (take action); cyclone bulletins follow separate stages.
Bay of Bengal and Arabian Sea	Two basins, two cyclone peaks: pre-monsoon and post-monsoon.
NCRMP	National Cyclone Risk Mitigation Project in eight coastal States: warnings, shelters, evacuation routes; Phase I completed 2018, Phase II 2023.

3 Additional information

Everything needed to answer this question well. Tier 1 holds what the demand needs; Tier 2 places it within the wider science of cyclones and forecasting.

TIER 1 · ESSENTIAL: THE MECHANISM, THE OUTCOMES AND THE EXAMPLES

How the Fujiwhara effect works



A schematic, not to scale. In an idealised pair, the common centre lies nearer the vortex with the stronger circulation, not simply the physically larger one. In the Southern Hemisphere the rotation is clockwise. Distance thresholds are approximate and vary with storm size and the surrounding flow.

Subject	What it is	Why it matters for the answer
THE EFFECT		
Origin	Named after Japanese meteorologist **Sakuhei Fujiwhara**, who described the mutual rotation of	Originator and year for the introduction.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

Subject	What it is	Why it matters for the answer
	vortices in water tank experiments and in a 1921 paper in the Quarterly Journal of the Royal Meteorological Society.	
Mechanism	Each cyclone's circulation steers the other. Close enough, the two begin to rotate around a common centre in the same sense as their own spin: anticlockwise in the Northern Hemisphere, clockwise in the Southern.	The core of Part 1.
Thresholds	Interaction may begin at roughly 1,400 km (some agencies cite about 1,200-1,350 km) and strengthens as the storms approach; around 650 km rotation may become pronounced; very close approaches, often about 150-300 km in idealised studies, may allow merger or straining-out.	Numbers, used as approximations.
POSSIBLE OUTCOMES		
Mutual orbit and escape	The storms orbit for a time and then separate, each on a changed track.	Tracks change; intensity may stay similar, rise or fall, depending on the interaction and the environment.
Merger	One circulation incorporates the other, which can enlarge or reorganise the storm without raising its peak wind. In August 1964 Typhoon Kathy absorbed Marie's circulation (19 August).	Size can grow; intensity need not.
Straining-out	The weaker vortex is elongated and disrupted by the dominant vortex's differential rotational flow, losing its coherent circulation and often dissipating.	Intensity of the smaller falls.
EXAMPLES		
Parma and Melor (2009)	Western Pacific: Parma looped and lingered near the Philippines while Melor approached, prolonging heavy rain.	Movement: stalling.
Hilary and Irwin (2017)	Eastern Pacific: Hilary's circulation slowed Irwin and turned it north-eastward; no merger; both weakened over cooler water.	Movement: deflection.
Seroja and Odette (2021)	Eastern Indian Ocean: Odette circled Seroja and dissipated; changed moisture and shear helped Seroja re-intensify before landfall.	Both movement and intensity.

Why the stronger usually dominates. The stronger circulation usually controls the shared motion, and interaction can deform the weaker vortex, raise vertical shear and disrupt its convection. But dominating is not intensifying: peak strength depends on shear, moisture and the ocean beneath. In Parma and Melor (2009), research even found the weaker Parma briefly strengthening during strong interaction.

Why forecasters care. Environmental steering currents still act on both cyclones, but mutual interaction adds another component to their motion and can produce unexpected track changes. Interacting storms can turn suddenly, stall or change speed, so ensemble forecasts and frequent warning updates matter more.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

TIER 2 · EXTENDED UNDERSTANDING: THE WHOLE TOPIC AROUND IT

Impact on movement

1. **Mutual orbit** around a common centre.
2. **Deflection:** both tracks bend.
3. **Loops and stalling:** long rain over one area.
4. **Speed changes** and sudden turns.

Impact on intensity

1. **Merger:** the dominant storm may strengthen.
2. **Shear:** the weaker storm is tilted and weakened.
3. **Competition** for warm, moist inflow.
4. **Ocean cooling:** if looping or stalling keeps a storm over one area, mixing and upwelling cool the sea and reduce its fuel.

Two debates worth knowing

Is every pair of nearby cyclones a Fujiwhara case?

No. Storms can be near each other while each follows its own steering flow. The balanced reading: **call it Fujiwhara only when the storms measurably rotate around each other**; one-sided pulls are partial interactions.

Will warming seas make it more common?

Warmer oceans may allow more storms to coexist in some basins, but the evidence on interactions is limited. The balanced reading: **a plausible risk to monitor**, not an established trend.

4 Pitfalls and variations

The mistakes that cost marks here, the claims never to make, and how the answer changes when the question changes.

4.1 Six pitfalls, each with its correction

Vague definition

~~Two cyclones collide and become one.~~

Two sufficiently close cyclonic vortices can influence each other's movement and rotate around a common centre.

No originator

~~It is a recently discovered phenomenon.~~

Described by Sakuhei Fujiwhara in 1921.

One outcome only

~~The two storms always merge.~~

They may orbit and separate, merge, or the smaller may be sheared out.

Mixed impacts

~~It changes the path and strength.~~

Movement: orbit, loops, stalling. Intensity: merger, shear.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

No examples

~~This has happened many times.~~

Parma and Melor (2009); Hilary and Irwin (2017); Seroja and Odette (2021).

No significance

~~Thus it is an interesting phenomenon.~~

It makes tracks erratic and warnings harder.

4.2 Never write these

- "The storms rotate clockwise in the Northern Hemisphere."
  Anticlockwise, the same sense as each storm's spin.
- "Fujiwhara is an American scientist."
  He was a Japanese meteorologist.
- "Both cyclones always weaken."
  The stronger may strengthen.
- "The common centre is always midway."
  In an idealised pair, it lies nearer the vortex with the stronger circulation, not necessarily the physically larger storm.
- "It occurs only in the Pacific."
  It has occurred in the Atlantic and Indian Oceans too.

4.3 If the question changes

If it asks	The structure becomes	What must change
Factors that decide a cyclone's **track**	Steering currents, beta drift, Fujiwhara, landfall	Fujiwhara is one factor.
Implications for **disaster management**	Forecast uncertainty, warnings, evacuation	The hidden demand becomes the answer.
Why do cyclones **weaken**	Landfall, shear, cool water, dry air, interaction	Intensity side only.
The same question for **15 marks**	Add outcomes, Indian Ocean examples, forecasting	Room for depth.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

5 The model answer

One model answer, written to the 150-word limit, in the form this question calls for: a short mechanism with a flow, then movement and intensity as separate points. The introduction covers the whole question; the conclusion settles its demand.

Model answer **Mechanism flow and points** **153 words**

Named after Japanese meteorologist Sakuhei Fujiwhara (1921), the Fujiwhara effect is the mutual interaction of two nearby cyclonic vortices, which can alter both storms' tracks and intensities.

About 1,400 km interaction possible → **Mutual orbit** common centre → **Outcome** separate, strain or merge

1. Impact on movement

- **Mutual orbit:** each circulation steers the other around a shared centre, anticlockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere.
- **Track changes:** deflection, loops and stalling; Parma repeatedly turned near the Philippines while interacting with Melor (2009).

2. Impact on intensity

- **Merger:** close vortices may combine, enlarging the storm without necessarily raising peak winds.
- **Straining and shear:** the weaker vortex may lose organisation as altered winds disrupt convection.
- **Varied outcomes:** stalling can cool waters through upwelling; yet Seroja re-intensified while interacting with Odette (2021).

Because outcomes depend on spacing, relative strength and surrounding conditions, the effect demands ensemble track forecasts and frequently revised coastal warnings from agencies like IMD.

DEMAND
Defined with mechanism, then movement and intensity separately

HIDDEN DEMAND
Varied outcomes make forecasts and warnings harder

STRUCTURE
About one-quarter mechanism, then movement and intensity

BALANCE
Introduction 27 words, conclusion 25 words; 153 words in all

Why it works: the introduction defines the effect and names its originator and year; the flow gives the approximate interaction distance, the shared orbit and the three broad outcomes; movement and intensity are kept apart as the question asks, with intensity shown as varied rather than predictable, each with a named example; the conclusion explains why the impact matters for forecasting.

6 Other ways to write it

The model answer above remains the answer. These outlines show how a different, equally valid answer could be built, and when each choice works.

Approach	How it is built	When it works
Diagram-led	Draw two vortices around a common centre; label thresholds; then points.	When drawing is quick for you.
Outcome table	Rows: orbit and escape, merger, straining-out; columns: movement, intensity.	When you want the variety at a glance.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

Approach	How it is built	When it works
Example-led	Open with Seroja and Odette (2021); then the mechanism.	When you want a vivid start.
For 15 marks	Add Indian Ocean cases and forecasting implications.	When there is room.

7 Quick recall and Prelims crossover

Facts for rapid revision and Prelims.

1	**Sakuhei Fujiwhara**: Japanese meteorologist.	9	**Kathy absorbed Marie**: **1964**.
2	Paper: **1921**, Quarterly Journal of the Royal Meteorological Society.	10	**Parma and Melor**: **2009**; Western Pacific.
3	Interaction noticeable within about **1,400 km**.	11	**Hilary and Irwin**: **2017**; track change, no merger.
4	Stronger interaction near about **650 km** (approximate).	12	**Seroja and Odette**: **2021**; Seroja re-intensified.
5	Merger possible at about **150-300 km** (idealised studies).	13	**Humberto and Imelda**: **2025**; asymmetric interaction.
6	**Anticlockwise** in the Northern Hemisphere.	14	Formation favoured by sea around **26.5°C** or warmer (guideline).
7	**Clockwise** in the Southern Hemisphere.	15	**RSMC New Delhi**: North Indian Ocean.
8	Common centre lies nearer the **stronger** circulation.	16	IMD colours: green, yellow (watch), orange (prepare), red (act).

THE ONE SENTENCE TO CARRY OUT OF THIS DOCUMENT

When nearby cyclones begin to steer each other on top of the prevailing winds, tracks turn, loop and stall, and forecasts are tested hardest.

8 Write it yourself

Write the answer in 150 words without looking back, then check it against each line below.

	Check	Yes / No
1	Is the effect **defined**, with Fujiwhara and 1921?	
2	Is a **distance threshold** given?	
3	Is the **direction** of rotation stated?	
4	Are **movement** and **intensity** treated separately?	
5	Is there at least one **named example**?	
6	Does the conclusion give the **significance**, at about the length of the introduction?	
7	Is it **150 words or a little over**, with no claim from section 4.2?	

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

Sources

- S. Fujiwhara, "The natural tendency towards symmetry of motion and its application as a principle in meteorology", Quarterly Journal of the Royal Meteorological Society (1921).
- M.A. Lander and G.J. Holland (1993), "On the interaction of tropical-cyclone-scale vortices. I: Observations", QJRMS; E.A. Ritchie and G.J. Holland (1993), "II: Discrete vortex patches", QJRMS; R. Prieto, B.D. McNoldy, S.R. Fulton and W.H. Schubert (2003), "A classification of binary tropical cyclone-like vortex interactions", Monthly Weather Review 131 (five categories: elastic interaction, partial and complete straining-out, partial and complete merger).
- Australian Bureau of Meteorology report on Tropical Cyclone Seroja (2021); Joint Typhoon Warning Center, Annual Typhoon Report 1964; US National Hurricane Center reports.
- NASA Earth Observatory and the US National Hurricane Center on Hilary and Irwin (2017) and Humberto and Imelda (2025).
- India Meteorological Department: cyclone warning system and RSMC New Delhi.
- UPSC Civil Services (Main): GS Paper I 2013, 2014, 2016, 2022, 2024 and 2026; GS Paper III 2026. Official question papers.

What is the Fujiwhara effect? Explain its impact on the movement and intensity of tropical cyclones.

YOUR NEXT STEP

Now write GS Paper I 2026 again.

You now know what this question asked, what it expected without saying so, and how its answer is built. Write the whole paper under the clock, have it evaluated, and read the feedback against this document.



1 Write the full paper in three hours — 2 Self-check this answer with section 8 — 3 Have the paper evaluated — 4 Read the feedback against this document

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