



GRAVITY AND VULNERABILITY IN THE GIG ECONOMY: A SPATIAL INTERACTION ANALYSIS OF JALESWAR TOWN, BALASORE DISTRICT, ODISHA

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Abstract: Jaleswar is a small town which is located in the northern part of Odisha. This town has shaped more by daily hustlers rather than corporate presence. This absence of formal economy has led the inhabitants of this town to depend more upon gig economy for sustainable livelihood. This work critically investigates the spatial vulnerability dynamics of street vendors in Jaleswar Town by integrating a gravity-based interaction modelling framework grounded in Reilly's Law of Retail Gravitation. This research is relied on primary survey data of 96 vendors across Jaleswar's market zone. The information from the survey data has been used to calculate the stress%, strain% and vulnerability ratio of each vendor. In this study Reilly's theoretical formulation has been used for the calculation of vendor-market interaction index i.e. $I = A \times B/D^2$. Here A stands for vulnerability score, B represents market mass and D reflects the vendor's distance from the main market centre. In this work, GIS analysis has been used to calculate and map all the indices of interaction index, i.e. A, B, D, I, vulnerability and breaking point (BP). This research work reveals that the shifts in vulnerability depends upon the closeness to the market especially within the gig economy. The study is based on a scientific framework and the findings are offering valuable insights for urban planners to implement location-sensitive interventions and promote more stable livelihoods for street vendors in Jaleswar Town.

IndexTerms - Gig Economy, Gravity Model, Jaleswar, Reilly's Gravity Theory, Street Vendors and Vulnerability

1. INTRODUCTION:

In the developing countries like India, where formal employment opportunities are very limited and scarce, there small towns plays pivotal role in the development process of regional economies (International Labour Organization [ILO], 2018; Observer Research Foundation [ORF], n.d.). There the inhabitants largely depend upon informal and semi-formal occupations for sustainable livelihood earning and growth of daily economic activities (ILO, 2018; Sekhani et al., 2019). Jaleswar is one such small town where the economic life is structured by gig or informal economic activities, rather than by formal or industrial sectors. Here the absence of formal economy has encouraged people to depend more upon gig economy, particularly street vending as a source of livelihood earning (Bhowmik, 2010; ILO, 2018; Sharma, 2016). In gig economy, street vending is an essential component. it not only helps in the economic growth of a small town but also, it ensures the inhabitants should get affordable goods and services, supports local supply chains and most importantly it generates source for self-employment (Khan & Dar, 2025; Sekhani et al., 2019). Though with the nature of flexibility and easy accessibility, the gig economy often lacks in providing adequate social protection and economic stability (ILO, 2018; Sekhani et al., 2019; Sharma, 2016). Especially for street vendors, being part of the gig economy means constant negotiation with the market space, demand, and mobility (Bhowmik, 2010). As a result, their vulnerability is not at all have uniformity across the market space. The vulnerability variation depends upon certain dimensions of spatial vulnerability such as market location, proximity to the market, footfall of customers and competition (Bhowmik, 2010; Sekhani et al., 2019). Understanding these spatial variations in vulnerability is therefore essential for inclusive urban planning and effective policy formulation (ILO, 2018; Khan & Dar, 2025; ORF, n.d.). In this research work, the concept of Reilly's law of retail gravitation has been used. This concept offers a robust analytical framework to understand the vendor-market relationship, pattern of street vendors distribution in the market area and the intensity of economic interaction within the Jaleswar's market system (Reilly, 1931; Haynes & Fotheringham, 1984). By using this gravity-based framework, it becomes quite easy to analyse how market mass and distance

influence vendor's stress, strain and vulnerability. This research work examines the spatial vulnerability among street vendors of Jaleswar town by integrating primary survey data with Reilly's gravity-based interaction model and application of GIS. The findings of this work aim to support practical urban planning decisions which will help in improving the livelihood stability for street vendors in small towns like Jaleswar.

1.1. LITERATURE REVIEW:

All kind of economic activities which operate outside the formal regulatory and taxation frameworks while continuing to contribute significantly to local livelihoods and urban development, come under gig economy (Chen, 2012). It is a system driven by unrecorded transactions, cash-dominant exchanges, trust-based and choice-based networks rather than institutional contracts (Schneider & Enste, 2000). Various studies have revealed that a large proportion of India's workforce (i.e. 90 %) is engaged in the informal sector (Kalyani, 2015). Measurement of gig economy is quite difficult due to its hidden nature. Traditional macro approaches use proxies such as cash-in-circulation, electricity consumption gaps, or model estimates of shadow GDP (Schneider & Medina, 2018). In gig economy, street vendors represent an important segment. Mostly in small towns and rural-urban fringe settlements, street vendors act as a catalyst for the economic growth of the region (Khan & Dar, 2025). They rely heavily upon short-duration, area specific economic opportunities which require constant adaptation to customer flow, competition, and mobility. Though this kind of work provides flexible and easily available livelihood options but at the same time they are also exposed to certain problems like economic uncertainty, absence of social security, legal protection and long-term income stability (Roever, 2014). Despite these challenges, the role of street vendors is very crucial in sustaining local economies as they provide affordable goods and services, supports market vitality and ensures everyday functioning of the urban spaces (Roever & Skinner, 2016). Here in this research work, Reilly's law of retail gravitation has been used as the primary analytical tool. It has been used to analyse the spatial interaction and vulnerability pattern of street vendors with the market centre (Fotheringham et al., 2000; Haynes & Fotheringham, 1984). Originally the law explains that the interaction strength between two area is directly proportional to their economic mass and inversely proportional to the square of the distance between them (Fotheringham et al., 2000). Mathematically, the interaction index is represented as:

$$I = A \times B / D^2$$

where, I denote interaction intensity, A and B represent the economic mass, and D represents the distance between A and B (Haynes & Fotheringham, 1984). In this research work, this gravity-based concept of Reilly has been used to suit the context of street vending and the gig economy. Here, I represent the interaction intensity, A represents the vulnerability score of street vendors, B denotes the market mass of Jaleswar main market and D represents the distance between vendors and the centre of main market. Through this concept, the research work tries to capture the effect of spatial proximity and market strength upon street vendor's livelihood vulnerability (Reilly, 1931). An important segment of Reilly's Law i.e. the concept of Breaking point (BP) has also been used in this study. Here, the breaking point represents zone of spatial threshold which separates low-vulnerability vendor zones from high-vulnerability vendor zones in Jaleswar's Town area.

1.2. OBJECTIVES:

- Analysing the spatial patterns of vulnerability among the street vendors in Jaleswar Town.
- Evaluating the interaction index (I), vulnerability score (A), market mass (B), distance (D), breaking point and influence of market proximity on the livelihood vulnerability of street vendors.

1.3. STUDY AREA:

Jaleswar block is one of the 12 administrative blocks of Balasore district. It is located at the northernmost part of the district at coordinates 21.8284°N and 87.2177°E. The area has a flat terrain with an average elevation of about 12.9 meters above sea level. It lies around 50–60 km from the Bay of Bengal and is traversed by the Subarnarekha River, often called the "placer gold river" of India. The total geographical area of Jaleswar block is approximately 246.03 sq. km. Administratively, it consists of 35 Gram Panchayats and one urban local body, the Jaleswar Municipality (Notified Area Council). Jaleswar town and the main market area lie within this municipal boundary. The Jaleswar Municipality covers an area of 12.14 sq. km, comprising 17 wards and 144 villages. It has a population of 25,747 (13,095 males and 12,652 females), with a sex ratio of 966 and a child sex ratio of 963. The literacy

rate here is relatively higher at 81.46% (male: 87.65%, female: 75.05%). Within the municipality, Hindus account for 80.22%, Muslims 17.48%, while SCs and STs constitute 7.48% and 9.56%, respectively. Fig. 1 shows the location of the study area.

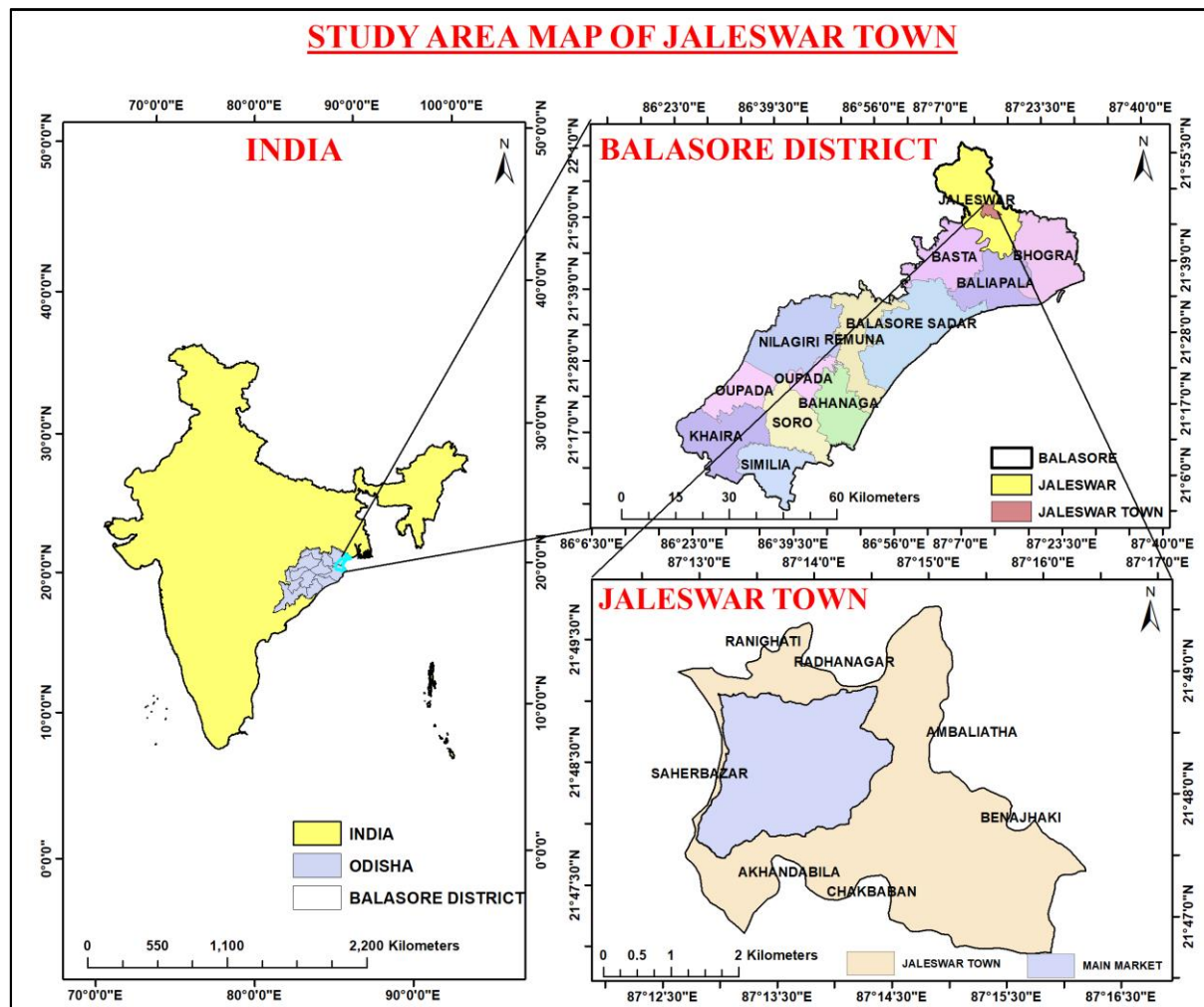


Fig. 1 Location Map of the Study Area

(Source: Generated by the author based on the census of India, 2011)

According to the 2011 Census, the block has a population of 1,77,743, including 90,917 males and 86,826 females, resulting in a sex ratio of 955 females per 1,000 males and a child sex ratio of 960. The Scheduled Caste (SC) population forms 19.7%, and the Scheduled Tribe (ST) population forms 9.7% of the total. The overall literacy rate of the block is 75.1%, with male literacy at 82.85% and female literacy at 67.4%. The population is mainly Hindu (93.38%), followed by Muslims (4.6%) and Christians (0.21%).

2. RESEARCH METHODOLOGY:

This study is based upon a field survey of 96 vendors from Jaleswar Area. The determination of sample size was based on the diversity of economic activities in the region and the feasibility of conducting detailed survey. This survey is based on qualitative research method where a purposive sampling technique was used. This is a type of non-probability sampling method. This is selected because it allows for the selection of the participants who are most relevant to the research objectives, namely street vendors who are actively engaged in the gig economy within the study area.

2.1. DATA COLLECTION: The data was collected through field surveys. All the respondents were above the age of 18 years. Data were collected by using a structured questionnaire, observations and semi structured interviews. The questions were designed to collect information on: (1). Vendor's operational costs (stress) of two months, (2). Vendor's profits (strain) of two months, (3). Quantitative data such as Rent, Electricity, Raw materials costs and Remuneration and (4). Qualitative data such as challenges faced by vendors.

2.2. DATA ANALYSIS:

2.2.1. Calculation Of Stress, Strain and Vulnerability Ratio: The operational cost (*stress%*) profit (*strain%*) and vulnerability ratio% of 96 vendors were calculated by using survey data and following mathematical formulas.

Percentage change in operational cost (OC) or Stress% was calculated by using Eq. (1).

$$((OC_{June} - OC_{May})/OC_{May}) \times 100$$

(1)

Percentage change in profit% or Strain% was calculated by using Eq. (2).

$$((Profit_{June} - Profit_{May})/Profit_{May}) \times 100$$

(2)

Calculation of Vulnerability Ratio(V): The Vulnerability ratio of each vendor was calculated by taking the ratio of stress% and strain% of each vendor. It was calculated by using Eq. (3).

$$Stress\%/Strain\%$$

(3)

By using the above formula, the vulnerability ratio values of 96 vendors were calculated and the observed values ranged from 0.025806 to 2.727273. When stress equals to strain, then the vulnerability ratio value is 1 which is called as theoretical equilibrium threshold (V=1). By using this, 96 vendors were classified into two categories:

- **Highly Vulnerable Vendors:** Out of 96 vendors, there are 30 vendors who fall in this category. Their *Vulnerability ratio* values are ≤ 1 and range of vulnerability ratio is 0.025806 to 1. This indicates that they are highly exposed to economic stress and they have limited adaptive capacity.
- **Low Vulnerable Vendors:** Out of 96 vendors, there are 66 vendors who fall in this category. Their *Vulnerability ratio* values are > 1 and range of vulnerability ratio is 1 to 2.727273. This indicates that they have, relatively stronger resilience against economic stress.

2.2.2. Calculation of Vulnerability Score(A): From the above classification of vendors, a *Vulnerability score* has been given to each vendor. Here *vulnerability score 1* represents vendors who fall in the category of high vulnerability and *vulnerability score 2* represents vendors who fall in the category of low vulnerability. Subsequently this vulnerability score has been used as the *socio-economic mass (A)* of Jaleswar market area in the gravity interaction model.

2.2.3. Market mass(B): In this study, the *market mass (B)* represents size of the Jaleswar's market area. Jaleswar town has only one dominant market which works as the main node of commercial exchange for all surveyed vendors. That is why the *market mass (B)* was assigned 1 for all vendors.

2.2.4. Calculation of Distance(D) from the Market centre: Distances of both high and low vulnerable vendors from the main market centre were calculated by using Euclidean distance analysis of Arc-GIS.

2.2.5. Calculation of Gravity Interaction(I): After acquiring all the parameters such as *Vulnerability score(A)*, *Market Mass(B)* and *Distance(D)* of 96 vendors, the interaction value of all vendors with the main market centre were calculated by using Eq. (4).

$$I = A \times B/D^2$$

(4)

2.2.6. Calculation of Breaking Point (BP): To identify the *Breaking point* between high and low vulnerable vendors, the mean centres for each group were calculated separately by using Spatial statistics tool's measuring geographic distribution analysis of Arc-GIS. Then the *Distance(D)* between both the centres were calculated by using Euclidean analysis of Arc-GIS and it is 3033.413548 Meter. 66 low vulnerable vendors were taken as *population B* and 30 highly vulnerable vendors were taken as *population A*. Then the breaking point was calculated by using the formula given by Reily as shown in Eq. (5).

$$BP = \frac{D}{1 + \sqrt{\frac{POPULATION\ B}{POPULATION\ A}}}$$

(5)

$$\frac{D}{1 + \sqrt{\frac{TOTAL\ NUMBER\ OF\ LOW\ VULNERABLE\ VENDORS}{TOTAL\ NUMBER\ OF\ HIGH\ VULNERABLE\ VENDORS}}} = \frac{3033.413548}{1 + \sqrt{\frac{66}{30}}} = 1221.55213\ \text{Meter}$$

Based upon all the above parameters, two separate tables i.e. Table 1 for low vulnerable vendors and Table 2 for highly vulnerable vendors have been prepared with the help of Ms- Excel to facilitate comparative analysis.

Table 1 Low vulnerable vendor's Stress, Strain, vulnerability ratio(V), vulnerability score(A), Market mass(B), Distance(D) and Interaction(I) values:

NUMBER OF VENDORS	STRESS IN PERCENTAGE	STRAIN IN PERCENTAGE	VULNERABILITY RATIO(V)	VULNERABILITY SCORE(A) 2= LESS VULNERABLE	MARKET MASS(B)=1	DISTANCE (D)FROM THE MARKET CENTRE	INTERACTION(I)
1	26.16984402	13.51351351	1.936568458	2	1	1336.670929	1.11939×10^{-06}
2	31.94805195	26.31578947	1.214025974	2	1	437.7325883	1.04379×10^{-05}
3	2.781546811	1.694915254	1.641112619	2	1	866.6588394	2.66277×10^{-06}
4	6.18556701	5.714285714	1.082474227	2	1	1021.429262	1.91696×10^{-06}
5	7.251908397	5.263157895	1.377862595	2	1	664.7207062	4.52639×10^{-06}
6	16.03427173	15.25423729	1.051135591	2	1	2024.105297	4.88162×10^{-07}
7	25.33333333	21.42857143	1.182222222	2	1	2422.703988	3.40745×10^{-07}
8	- 20.07575758	- 16.66666667	1.204545455	2	1	1897.952046	5.55213×10^{-07}
9	18.64915572	15.78947368	1.181113196	2	1	1552.429071	8.29863×10^{-07}
10	4.600484262	3.571428571	1.288135593	2	1	1117.764998	1.60077×10^{-06}
11	3.242955875	3	1.080985292	2	1	1089.150239	1.68599×10^{-06}
12	9.677419355	8.771929825	1.103225806	2	1	1381.291512	1.04824×10^{-06}
13	16.66666667	10	1.666666667	2	1	910.111936	2.41457×10^{-06}
14	48.14814815	38.88888889	1.238095238	2	1	646.69312	4.78226×10^{-06}
15	-10.9375	- 7.142857143	1.53125	2	1	1173.730819	1.45175×10^{-06}
16	10.73684211	7.142857143	1.503157895	2	1	784.2585225	3.25171×10^{-06}
17	8.189233279	3.333333333	2.456769984	2	1	1387.839161	1.03837×10^{-06}
18	3.773584906	3.333333333	1.132075472	2	1	1533.138048	8.50878×10^{-07}
19	-6.25	- 3.333333333	1.875	2	1	2366.819987	3.57026×10^{-07}
20	- 12.30863442	- 10.71428571	1.148805879	2	1	1350.687233	1.09628×10^{-06}
21	16.93548387	7.692307692	2.201612903	2	1	205.5126548	4.73536×10^{-05}
22	9.275362319	8.571428571	1.082125604	2	1	986.5855823	2.05476×10^{-06}
23	7.236842105	6.666666667	1.085526316	2	1	1122.81955	1.58639×10^{-06}
24	6.52173913	5.357142857	1.217391304	2	1	2029.777186	4.85437×10^{-07}
25	11.27659574	6.25	1.804255319	2	1	1732.984225	6.65949×10^{-07}
26	9.677419355	9.090909091	1.064516129	2	1	917.0796132	2.37802×10^{-06}
27	15.15151515	5.555555556	2.727272727	2	1	1330.106793	1.13046×10^{-06}
28	8.664259928	5.263157895	1.646209386	2	1	1892.423068	5.58462×10^{-07}

29	30.45592705	18.18181818	1.675075988	2	1	2478.735 588	3.25514 × 10 ⁻⁰⁷
30	6.482593037	4.761904762	1.361344538	2	1	2277.264 84	3.85659 × 10 ⁻⁰⁷
31	- 18.51851852	- 16.66666667	1.111111111	2	1	1220.405 232	1.34283 × 10 ⁻⁰⁶
32	8.401976936	5.714285714	1.470345964	2	1	1170.807 137	1.45901 × 10 ⁻⁰⁶
33	32.53402463	15.85365854	2.052146169	2	1	1877.853 099	5.67162 × 10 ⁻⁰⁷
34	24.60567823	10	2.460567823	2	1	1571.283 725	8.10067 × 10 ⁻⁰⁷
35	12.53071253	5.714285714	2.192874693	2	1	1852.290 461	5.82924 × 10 ⁻⁰⁷
36	6.288532676	5	1.257706535	2	1	1951.392 469	5.25219 × 10 ⁻⁰⁷
37	6.566970091	6	1.094495015	2	1	1904.643 511	5.51319 × 10 ⁻⁰⁷
38	16.66666667	13.33333333	1.25	2	1	2318.310 993	3.72123 × 10 ⁻⁰⁷
39	10.03937008	8	1.25492126	2	1	2187.667 02	4.17895 × 10 ⁻⁰⁷
40	- 14.61086637	- 5.714285714	2.556901615	2	1	1932.231 623	5.35688 × 10 ⁻⁰⁷
41	- 12.84521516	- 7.894736842	1.627060587	2	1	2021.480 407	4.89430 × 10 ⁻⁰⁷
42	4.275862069	4.166666667	1.026206897	2	1	1859.081 066	5.78673 × 10 ⁻⁰⁷
43	4.6875	2.857142857	1.640625	2	1	2918.371 196	2.34827 × 10 ⁻⁰⁷
44	15.55555556	11.11111111	1.4	2	1	1454.634 534	9.45197 × 10 ⁻⁰⁷
45	10.85590466	8.108108108	1.338894908	2	1	1380.948 426	1.04876 × 10 ⁻⁰⁶
46	6.161021109	5.882352941	1.047373589	2	1	1409.615 301	1.00653 × 10 ⁻⁰⁶
47	13.63106796	13.15789474	1.035961165	2	1	1846.168 533	5.86796 × 10 ⁻⁰⁷
48	31.67192429	23.07692308	1.372450053	2	1	1429.600 027	9.78590 × 10 ⁻⁰⁷
49	16.61237785	8.333333333	1.993485342	2	1	1856.639 077	5.80196 × 10 ⁻⁰⁷
50	12.20095694	9.090909091	1.342105263	2	1	2059.753 97	4.71411 × 10 ⁻⁰⁷
51	23.25581395	21.42857143	1.085271318	2	1	1984.133 596	5.08029 × 10 ⁻⁰⁷
52	18.18181818	14.28571429	1.272727273	2	1	2031.562 312	4.84585 × 10 ⁻⁰⁷
53	24	18.18181818	1.32	2	1	1440.918 851	9.63276 × 10 ⁻⁰⁷
54	24.3902439	16.66666667	1.463414634	2	1	1880.794 386	5.65389 × 10 ⁻⁰⁷
55	19.04761905	14.28571429	1.333333333	2	1	1246.821 411	1.28653 × 10 ⁻⁰⁶
56	18.987	13.786	1.377266792	2	1	2898.862 884	2.37999 × 10 ⁻⁰⁷
57	25.9876	18.987	1.368704903	2	1	2085.588 456	4.59804 × 10 ⁻⁰⁷
58	21.09098	16.098	1.310161511	2	1	1790.383 114	6.23933 × 10 ⁻⁰⁷
59	20.9876	11.098	1.891115516	2	1	3119.243 532	2.05557 × 10 ⁻⁰⁷
60	19.98765	9.987	2.001366777	2	1	2816.800 663	2.52068 × 10 ⁻⁰⁷
61	18.654	12.987	1.436359436	2	1	2636.050 342	2.87821 × 10 ⁻⁰⁷

62	26.9876	19.0989	1.41304473	2	1	2547.070 195	3.08282×10^{-7}
63	23.123	19.7686	1.169683235	2	1	2670.563 911	2.80430×10^{-7}
64	22.456	18.0987	1.240752098	2	1	2229.919 863	4.02209×10^{-7}
65	21.5656	19.87654	1.084977567	2	1	1938.967 717	5.31972×10^{-7}
66	20.6768	17.987	1.149541335	2	1	1662.869 926	7.23292×10^{-7}

Note: $V = \text{stress (\%)} / \text{strain (\%)} \text{ and } I = A \times B / D^2$

(Source: prepared by the author using primary survey responses of vendors, MS -Excel and Arc-GIS tool)

Table 2 Highly vulnerable vendor's Stress, Strain, Vulnerability ratio(V), Vulnerability score(A), Market mass(B), Distance(D) and Interaction(I) values:

NUMBER OF VENDORS	STRESS IN PERCENTAGE	STRAIN IN PERCENTAGE	VULNERABILITY RATIO(V)=	VULNERABILITY SCORE(A) 1= HIGHLY VULNERABLE	MARKET MASS(B) =1	DISTANCE (D) FROM THE MARKET CENTRE	INTERACTION(I)
1	27.14286	30.43478	0.509116	1	1	2601.833	1.47721×10^{-7}
2	25.98039	33.33333	0.666667	1	1	2991.754	1.11724×10^{-7}
3	20.38835	25	0.025806	1	1	2722.506	1.34916×10^{-7}
4	13.88499	27.27273	0.358974	1	1	3184.946	0.98582×10^{-7}
5	13.33333	20	0.588086	1	1	2448.345	1.66823×10^{-7}
6	11.22807	21.42857	0.3875	1	1	3358.776	0.88642×10^{-7}
7	10.36585	15.38462	0.67378	1	1	2405.162	1.72867×10^{-7}
8	9.722222	15.78947	0.232653	1	1	2414.058	1.71595×10^{-7}
9	8.660131	25	0.311111	1	1	2763.943	1.30901×10^{-7}
10	7.894737	11.11111	0.523977	1	1	2795.787	1.27936×10^{-7}
11	7.669173	12	0.815534	1	1	3632.592	0.75782×10^{-7}
12	7.259953	10	0.629032	1	1	2969.02	1.13442×10^{-7}
13	6.918239	13.33333	0.518868	1	1	3047.236	1.07693×10^{-7}
14	6.666667	21.42857	0.615741	1	1	3866.226	0.66900×10^{-7}
15	6.349206	33.33333	0.630769	1	1	4473.554	0.49968×10^{-7}
17	6.122449	26.31579	0.330535	1	1	3292.462	0.92248×10^{-7}
18	5	12.90323	0.639098	1	1	3611.985	0.76649×10^{-7}
19	4.83871	7.692308	0.725995	1	1	3394.637	0.86779×10^{-7}
20	4.036697	31.03448	0.187593	1	1	4674.797	0.45759×10^{-7}
21	3.657143	3.703704	0.987429	1	1	3996.437	0.62612×10^{-7}
22	3.322785	8.333333	0.130071	1	1	4199.492	0.56703×10^{-7}
23	3.311582	12.5	0.251524	1	1	3626.134	0.76052×10^{-7}
24	2.756654	4.6875	0.326667	1	1	4214.756	0.56293×10^{-7}
25	2.605459	13.88889	0.891837	1	1	4339.012	0.53115×10^{-7}
26	1.676829	6.666667	0.710526	1	1	4139.056	0.58371×10^{-7}
26	2.203568	6.666667	0.264927	1	1	4497.135	0.49446×10^{-7}
27	0.645161	25	0.346405	1	1	3944.715	0.64264×10^{-7}
28	-3.5	-10.7143	0.779412	1	1	3978.797	0.63168×10^{-7}
29	-3.84615	-10.7143	0.190476	1	1	4333.766	0.53244×10^{-7}
30	-15.7692	-25	0.398734	1	1	4432.704	0.50894×10^{-7}

Note: $V = \text{stress (\%)} / \text{strain (\%)} \text{ and } I = A \times B / D^2$

(Source: prepared by the author using primary survey responses of vendors, MS -Excel and Arc-GIS tool)

3. DISCUSSION:

3.1. Jaleswar Vendors' Spatial Distribution: The Fig. 2 represents the spatial distribution of 96 vendors across the Jaleswar town area with relation to the main market area. All the vendors are indicated as point features. The yellow color region represents the Jaleswar town area and the light blue color region represents the Main market area of Jaleswar Town. From Fig. 2 we can clearly see a noticeable concentration of vendors in and around the main market area. The gathering of these 96 vendors around the market area represents the strong attraction force of the central market place. This central market place plays the role of primary economic nucleus of Jaleswar town. From the geographic point of view, such proximity to the main market gives vendors higher customer footfall, better accessibility, and reduced transportation and transaction costs.

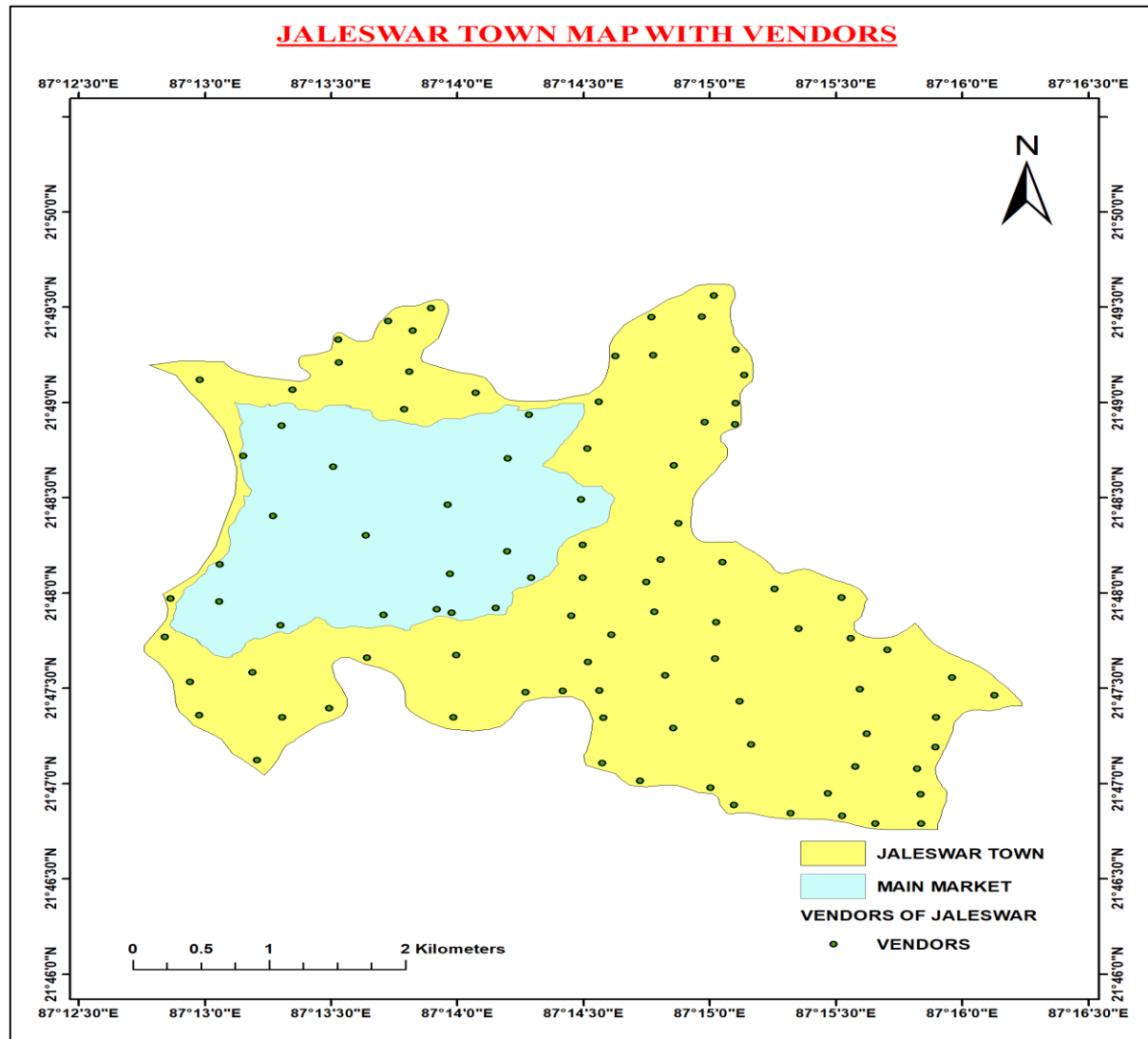


Fig. 2 Spatial distribution of 96 vendors across the Jaleswar town
(Source: Generated by the author based on the conducted primary survey)

However, the spatial distribution of vendors from the Figure 2 reveals the existence of gravity-interaction model, where vendor's economic resilience and vulnerability increases when the distance from the main market decreases.

3.2. Vendor's Distribution based upon Vulnerability Score (A): The Fig. 3 represents the spatial distribution of 96 vendors based upon their respective vulnerability score. We can observe that vendors with low vulnerability are represented as green point feature while vendors with high vulnerability are represented as red point feature. The yellow region in the map represents the area covered by low vulnerable vendors and blue region in the map represents the area covered by highly vulnerable vendors. we can observe that all highly vulnerable vendors are highly concentrated in the south-eastern part of the Jaleswar town, forming a contiguous zone of economic fragility. These vendors are quiet far from the primary market area due to which they face weaker market access, low customer foot fall and high economic vulnerability. On the other hand, the central and western part of the Jaleswar town is highly dominated by the low vulnerable vendors. Their proximity to the main market centre as compared to highly vulnerable vendors is quiet less. There for these low vulnerable vendors experience better economic stability, consistent demand, and stronger spatial integration with urban commercial activity.

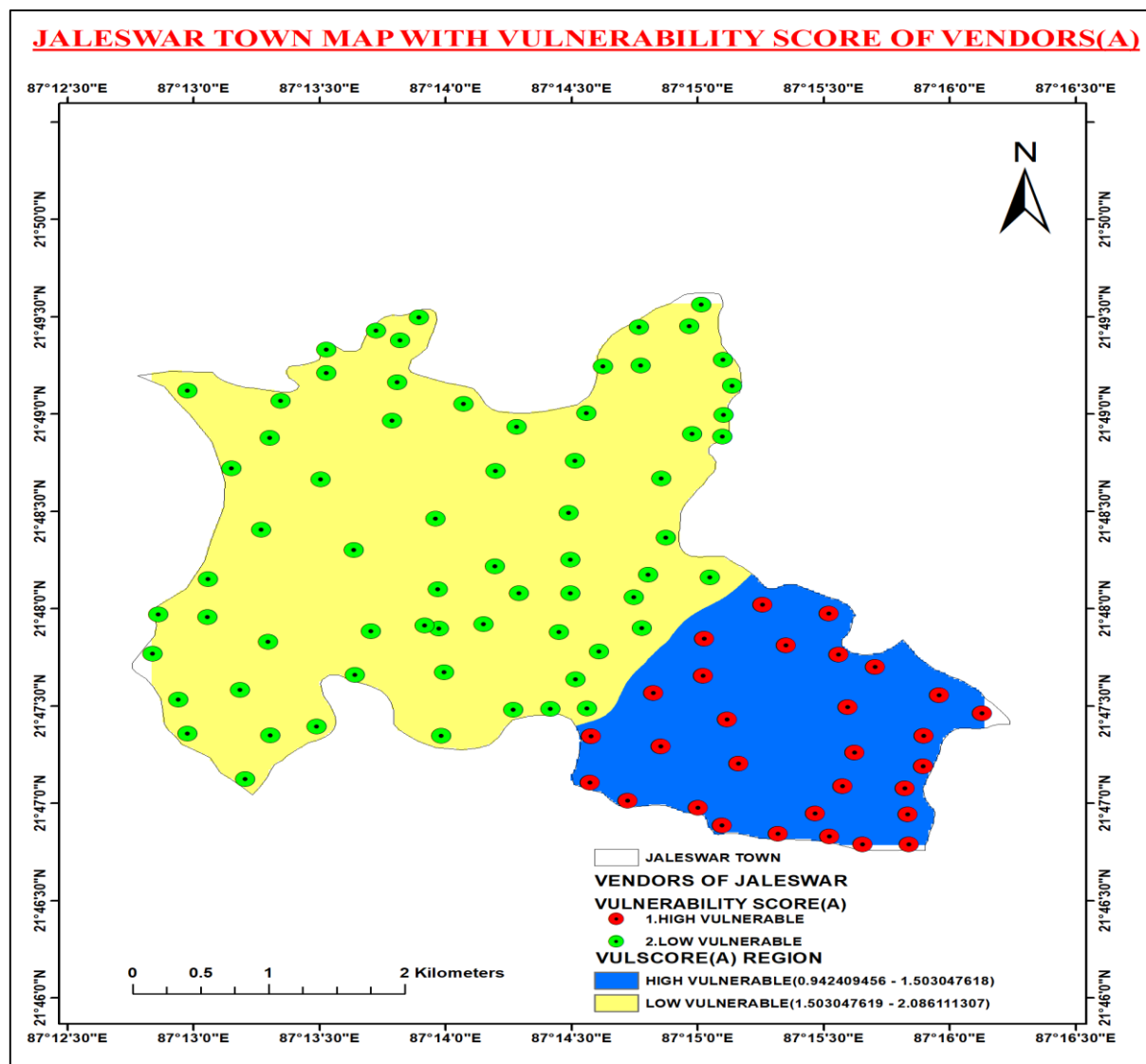


Fig. 3 Spatial distribution of vendors based upon Vulnerability score(A)
(Source: generated by the author based on the conducted primary survey)

3.3. Role of Transportation Networks and Vendor's Vulnerability in Jaleswar Town: The Fig. 4 represents the transportation corridor of Jaleswar town area. Mainly NH-16 and the railway line which connects Jaleswar town with capital of Odisha i.e. Bhubaneswar and with capital of West Bengal i.e. Kolkata, play an important role in shaping the structure and function of the gig economy in Jaleswar area. Jaleswar town is just 8–10 km far from the West Bengal border, which gives the area a strong cross-border trade advantage. This also helps in the quick and smooth movement of goods, people, and services. This easy access encourages the growth of informal businesses in the town. The central market area has direct access to both NH-16 and the railway station. From the Fig. 4, we can observe that all the low vulnerable vendors are highly concentrated along the major transportation corridor, near to the market center and railway station. This benefits them by having better customer foot fall, cheap transportation cost and better mobility. On the other hand, all the vendors with high vulnerability are located at the peripheral zone of transportation corridor. They are also very far from the main market center and the railway station. Such limited access to major transportation spine causes them with low market interaction and less customer flow. This also increases their transaction costs and heightens their uncertainty in economic stability.

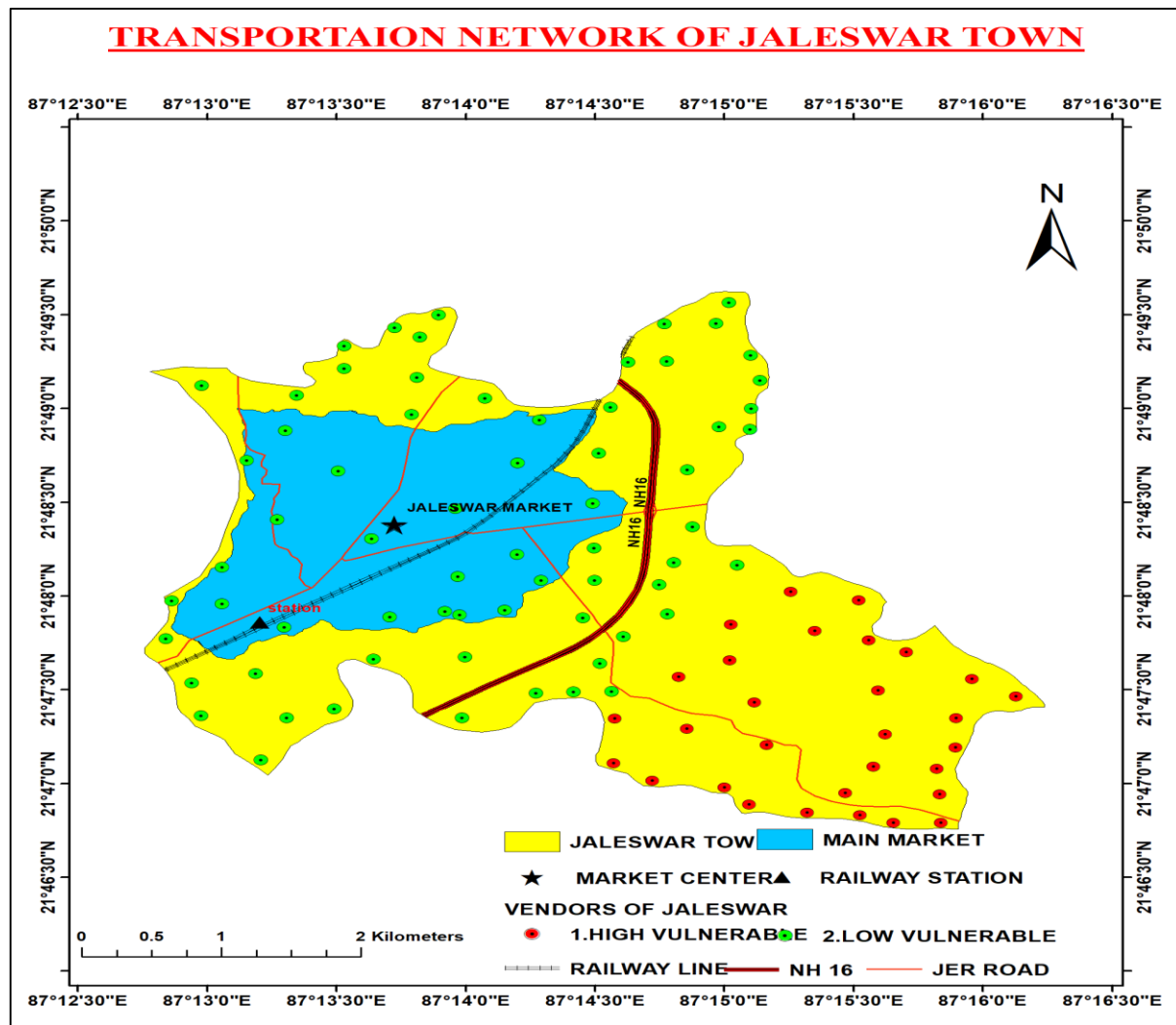


Fig. 4 Transportation corridor and distribution of Informal vendors in Jaleswar town
(Source: generated by the author based on the conducted primary survey and Census of India, 2011)

3.4. Jaleswar Main Market Mass (B) and Vendors-Market Interaction: The Fig. 5 represents the Market Mass(B) parameter of the Reilly's gravity-interaction model. The Jaleswar Town has only one primary market center. Therefore its mass has been standardized as $B = 1$. This standardization ensures that spatial interaction has been influenced primarily by vendor's vulnerability score (A) and distance (D). The map also reveals that that low vulnerable vendors are concentrated around the market core due to which they are reflecting stronger economic ties and highly vulnerable vendors are subsequently located around the peripheral areas, where greater distance from the market center weakens their interaction and increases their economic vulnerability.

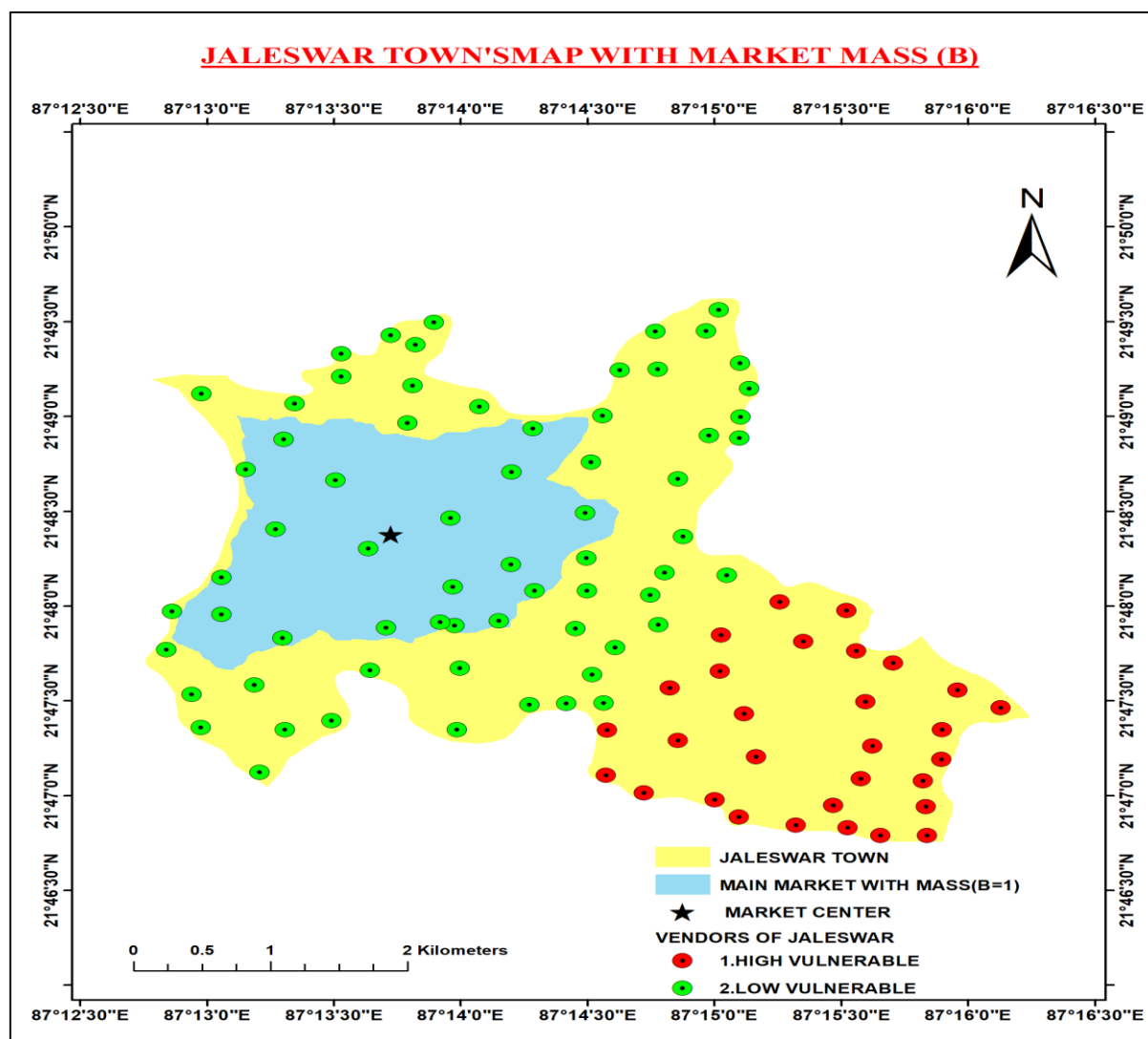


Fig. 5 Jaleswar town's Main Market with Mass B and interaction with Vendors
 (Source: generated by the author based on the conducted primary survey)

3.5. Distance(D) of Low and Highly Vulnerable vendors from the Main Market Centre: The Fig. 6 represents the Distance(D) parameter of the Reilly's gravity-interaction model. The Blue and Pink lines on the map represents the Euclidean distances of low and highly vulnerable vendors from the main market center respectively. The map also reveals that the low vulnerable vendors are located closer to the main market center, which represents that they have very high accessibility over the market area and reduced distance decay. On the other hand, highly vulnerable vendors are located very far from the main market center. This increased distance causes them with weak economic interaction with the market area.

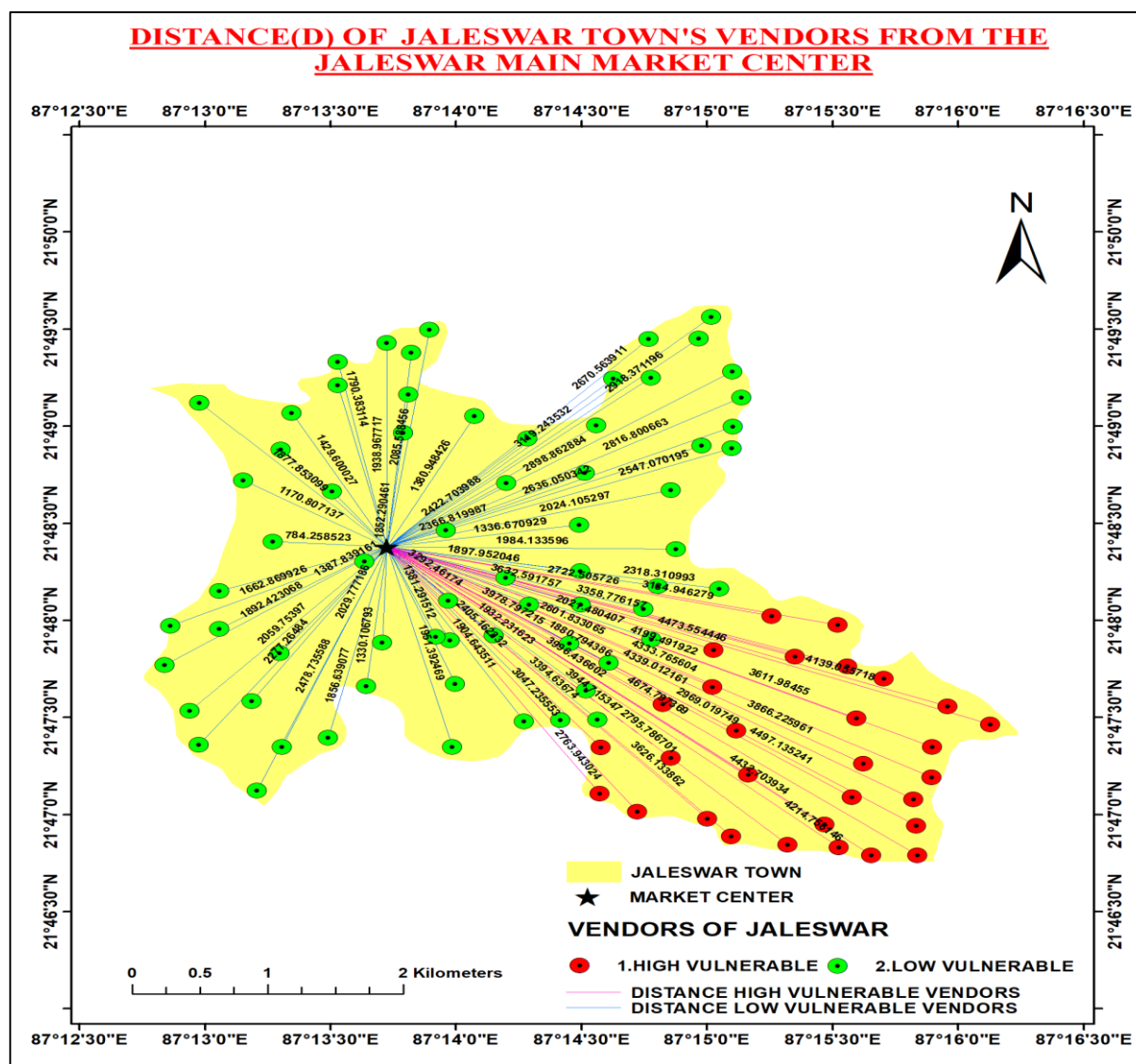


Fig. 6 Distance(D) of low and highly vulnerable vendors from the Market centre

(Source: Generated by the author based on the conducted primary survey and Arc-GIS software)

3.6. Interaction(I) of Low and Highly Vulnerable Vendors with the Main Market Centre: The Fig. 7 represents the Interaction(I) parameter of the Reilly's gravity- interaction model. The interaction(I) values of both the low and highly vulnerable vendors have been calculated by using formula given by Reilly.

$$I = A \times B / D^2$$

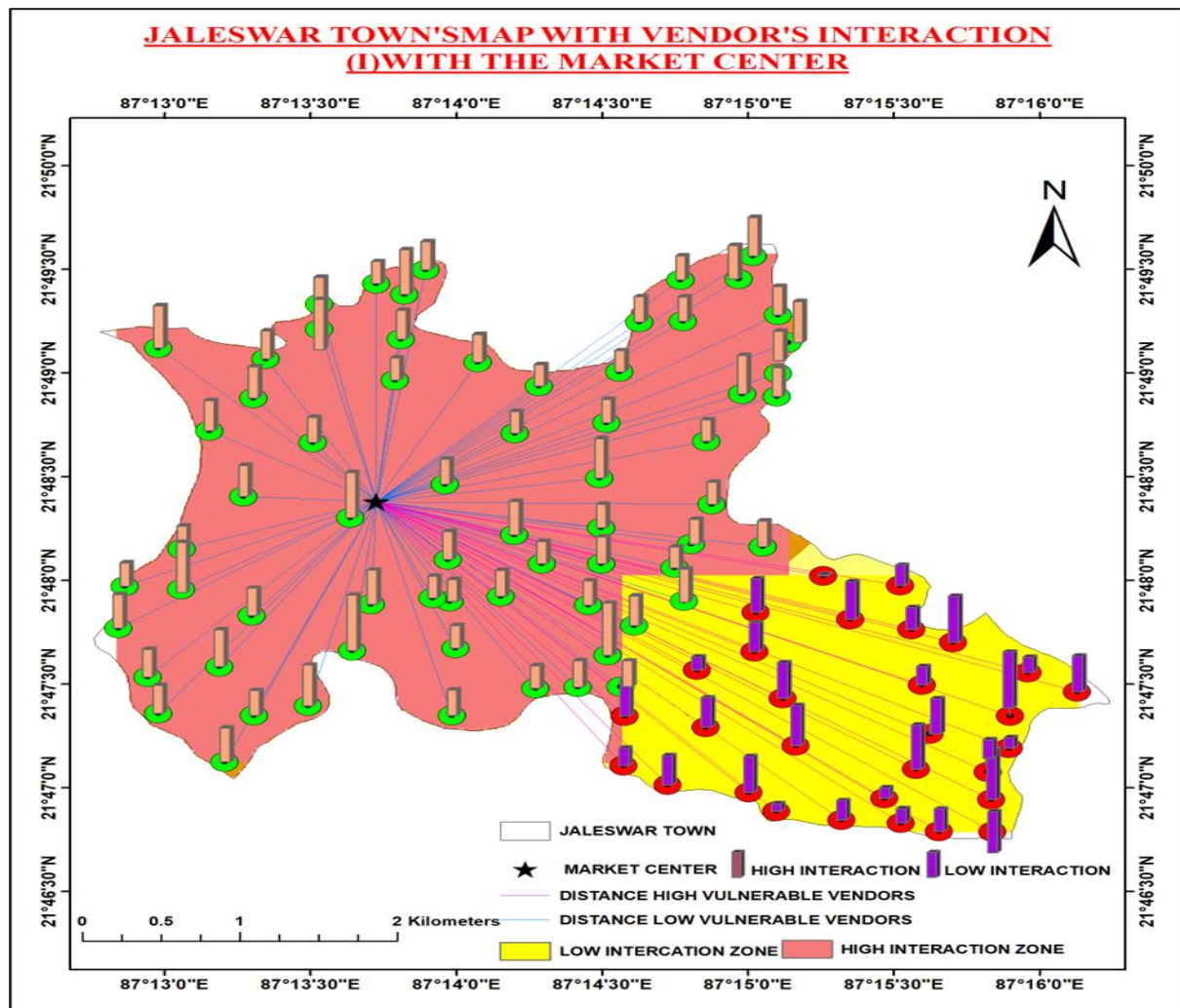


Fig. 7 Interaction(I) of low and highly vulnerable vendors from the Market centre

(Source: Generated by the author based on the conducted primary survey and Arc-GIS software)

From the map it is clear that, light brown colour zone i.e. High interaction zone is predominant in the central and western part of the town. Here vendors are predominantly low vulnerable and they are located close to the market centre. These gig economy vendors have higher platform accessibility, lower transportation cost and they are having stable and predictable earnings. Their stronger interaction with the market centre suggests that they have better integration with the gig economy market network. On the other hand, the southern -eastern part and peripheral areas represented by yellow colour zone indicates the low interaction zone. Here vendors are having subsequently lower interaction with the market centre. In this low interaction zone, they are clustered and they have greater distance from the main market centre. This increase of distance is not only affecting their economic sustainability but also reducing their interaction with the main market place. This reduced interaction implies fewer customers, irregular income, and greater exposure to economic shocks. This spatial difference between interaction zones of low and highly vulnerable vendors is clearly indicating the distance-decay effect embedded in the gravity-interaction model of Reilly.

3.7. Comparative Analysis and Economic Interpretation:

Table 3 Comparative analysis of parameters of low and highly vulnerable vendors

PARAMETERS	LOW VULNERABLE VENDORS	HIGHLY VULNERABLE VENDORS
TOTAL NUMBER OF VENDORS	66	30
MAXIMUM STRESS%	48.14814815	27.14285714
MINIMUM STRESS%	-20.075	-15.76923077
MEAN STRESS%	12.85129828	6.684194316
MAXIMUM STRAIN%	26.31578947	30.43478261
MINIMUM STRAIN%	-16.6666667	-25
MEAN STRAIN%	9.246894009	14.26046155
MAXIMUM VULNERABILITY RATIO(V)	2.727273	0.987428571
MINIMUM VULNERABILITY RATIO(V)	1.035961165	0.025806452

MEAN VULNERABILITY RATIO(V)	1.457628967	0.488294824
VULNERABILITY SCORE(A)	2	1
MARKET MASS(B)	1	1
MAXIMUM DISTANCE FROM THE MARKET CENTRE(Meter)	3119.243	4674.797369
MINIMUM DISTANCE FROM THE MARKET CENTRE(Meter)	205.512	2405.162232
MEAN DISTANCE FROM THE MARKET CENTRE(Meter)	1699.134	3545.054066
MAXIMUM INTERACTION VALUE(I)	4.73536×10^{-05}	1.72867×10^{-7}
MINIMUM INTERACTION VALUE(I)	2.05557×10^{-07}	0.45759×10^{-7}
MEAN INTERACTION VALUE(I)	1.8422×10^{-6}	9.03695×10^{-8}

(Source: Prepared by the author using data from Table 1 and Table 2)

The Table 3 represents the comparative analysis of different gravity-interaction parameters of both the low and highly vulnerable vendors in the Jaleswar town area. In terms of population, the total number of low vulnerable vendors is 66. This is more than the double of total number of highly vulnerable vendors i.e. 30. This larger size itself contributes to stronger collective resilience and market integration. The Stress parameter indicates that as compare to highly vulnerable vendors, the low vulnerable vendors experience higher economic stress. Their maximum stress 48.15% and mean stress 12.85% are very high from highly vulnerable vendors i.e. maximum stress 27.14% and mean stress 6.68%. This signifies that although low vulnerable vendors are facing very high operational pressures such as competition, rent and market exposure than the highly vulnerable vendors, but at the same time they possess greater coping capacity. On the other hand, highly vulnerable vendors have significantly high Strain value. The mean strain value of highly vulnerable vendor is 14.26% which is higher than the mean strain value of low vulnerable vendors i.e. 9.25%. The maximum strain value of highly vulnerable vendors is 30.43%, which is also greater than the maximum strain value of low vulnerable vendors i.e. 26.32%. This signifies that highly vulnerable vendors are less capable of absorbing shocks, so even moderate stress translates into higher strain, reinforcing their fragile economic condition.

This strong stress-strain difference of high and low vulnerable vendors, has also been reflected in their respective vulnerability ratio (V). Low vulnerable vendors are having high mean vulnerability ratio of 1.46 as compared to highly vulnerable vendors' mean vulnerability ratio i.e. 0.49. This signifies that the low vulnerable vendors have better stress-strain balance and adaptive capacity, whereas the very low mean ratio of highly vulnerable vendors indicate structural weakness and poor economic shock absorption.

The distance factor plays a decisive role in the economic resilience in gig economy. The mean distance of highly vulnerable vendors from the market centre is 3545 m whereas the mean distance of the low vulnerable vendors from the market centre is 1699 m. this difference of distances indicates that the highly vulnerable vendors are spatially more marginal than the low vulnerable vendors. Even the minimum distance of highly vulnerable vendors which is 2405 m exceeds the mean distance of low vulnerable vendors. This exclusion limits the highly vulnerable vendors from heavy customers flow, easy transportation access, and daily market opportunities.

Just like distance, the interaction value(I) also plays decisive role in strengthening the economic resilience in gig economy. The mean interaction value of low vulnerable vendor is 1.84×10^{-6} and for the highly vulnerable vendors, it is 9.04×10^{-8} . This indicates that the low vulnerable vendors have nearly 20 times stronger interaction with the market centre than the highly vulnerable vendors. This confirms that proximity and better socio-economic capacity jointly strengthen vendor-market interaction.

This comparative analysis indicates that, though low vulnerable vendors are facing higher economic stress in their businesses but they are at the upper economic stage than the highly vulnerable vendors through strong economic resilience, closer market proximity, and significantly higher interaction intensity. This proves that vulnerability among gig economy vendors in Jaleswar Town is not only an economic condition but also a spatially reinforced socio-economic process, which is fully consistent with gravity-based interpretations of market influence and Reilly's Law.

3.8. Breaking Point (BP) between Low and Highly Vulnerable Vendors: The Fig. 8 represents the breaking point map of Jaleswar town. From the below map we can see that yellow and blue region represents low vulnerable and highly vulnerable vendors' zone respectively. The pink and green star represents the mean center of low and highly vulnerable vendors' zone respectively. The distance between both the mean center is 3033.413548 m which is taken as Distance(D) for the breaking point

calculation. By using Reilly's breaking point formula and by using population mass values of $A = 30$ for highly vulnerable vendors and $B = 66$ for low vulnerable vendors, the breaking point was located at 1221.56 meters from the mean centre of the low vulnerable vendors. This means that all the low vulnerable vendors have higher influence over a larger part of the Jaleswar town than highly vulnerable vendors. This breaking point acts as a spatial indicator for economic inequality among gig economy vendors and reveals how the Vulnerability ratio(V), vulnerability score(A), Market Mass(B), Distance(D), and market interaction force(I) help in structuring the informal economic landscapes in Jaleswar Town.

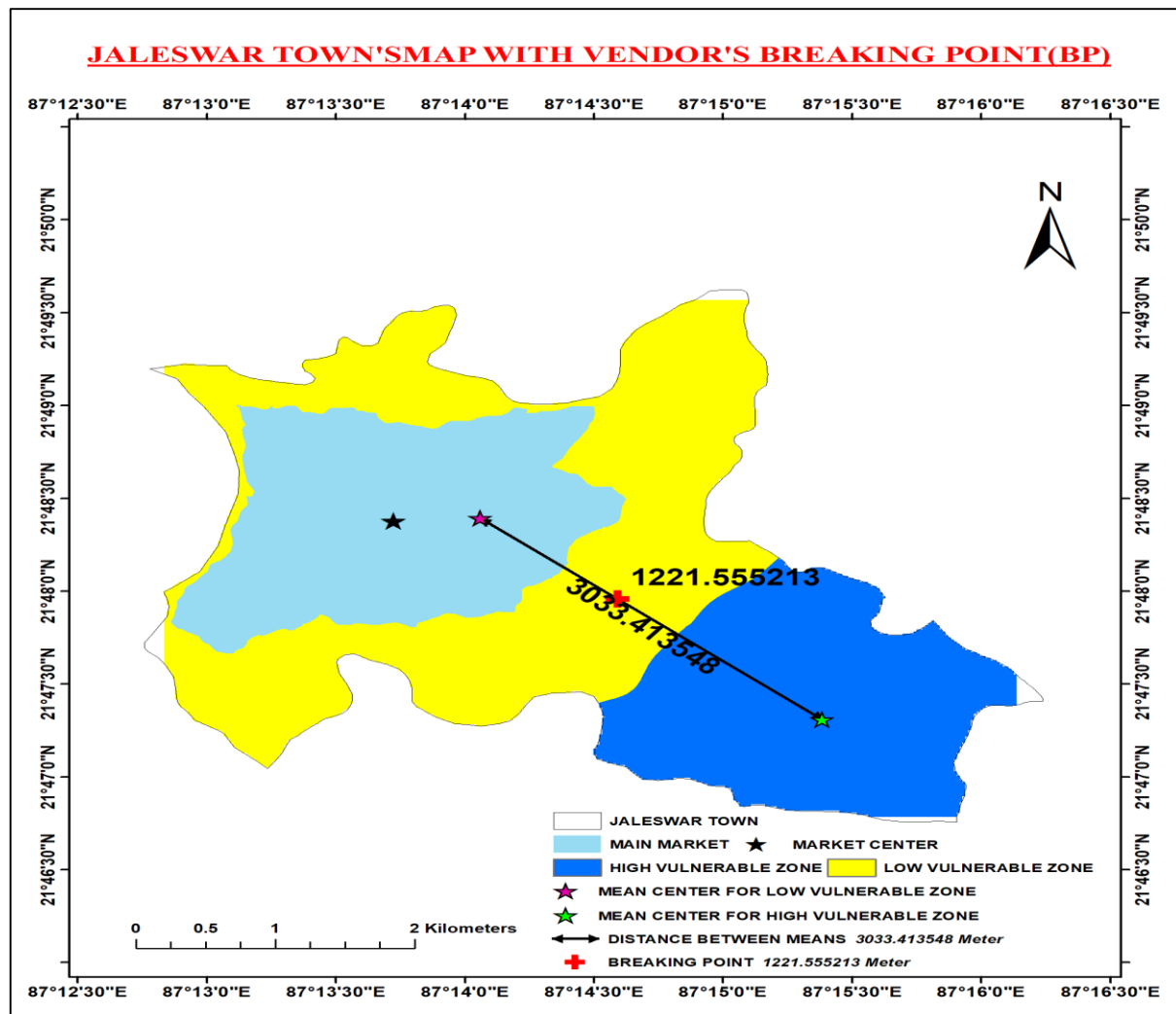


Fig. 8 Breaking Point (BP) between High and low vulnerable vendors
(Source: Generated by the author by using Euclidean distance and Arc-GIS software)

4. CONCLUSION:

This research work follows an innovative interdisciplinary approach. It offers a fresh analytical perspective to understand the evolving gig economy dynamics in Jaleswar area through the lens of Reilly's gravity-interaction model. This research work proves that, the economic vulnerability among gig economy vendors in Jaleswar town is not random but it is shaped by the integration of economic capacity of Jaleswar town and spatial location of informal vendors. Out of 96 gig economy vendors, vendors with low vulnerability ratio(V) form larger group by having 66 vendors as compared to 30 highly vulnerable vendors. Though these 66 low vulnerable vendors are experiencing high economic stress such as high market competition, higher operating costs and higher market exposure but they are significantly able to cope with these pressures. These low vulnerable vendors also have lower strain values which also indicates that they can easily absorb economic shocks without having severe economic damage to their livelihood. In contrast, highly vulnerable vendors show lower stress but much higher strain than the low vulnerable vendors. This indicates that their businesses are not that much capable of handling economic pressure and this makes them structurally fragile. The analysis of this research work also represents that vendor vulnerability in Jaleswar town is strongly controlled by both economic resilience and spatial location. Highly vulnerable vendors are located at a far distance from the main market centre with limited access to customers, transport routes, and daily market flows. The gravity-based interaction results confirm this pattern, with low vulnerable vendors showing interaction values nearly twenty times higher than those of highly vulnerable vendors. The breaking point analysis also supports this spatial inequality, as the breaking point lies far from the highly vulnerable vendors' mean centre. This indicates

that highly vulnerable vendors have weaker market influence. Overall, the findings of this research paper proves that vulnerability of informal vendors within the gig economy of Jaleswar town is a spatially structured outcome which is produced by the combined effects of economic capacity and market accessibility.

5. POLICY RECOMMENDATIONS:

- Vendors with high vulnerability ratio who are located far from the breaking point should be given location specific economic policy support.
- Creating designated vending zones, subsidized stalls and mobile market access closer to high-interaction corridors.
- Setting up organized spots for highly vulnerable vendors close to NH-16 - also near railway station stops and main streets of Jaleswar town.
- Ensuring electricity, shade, kiosks, and security for highly vulnerable vendors to support economic stability.
- Creating another decentralized market node or secondary market hub for highly vulnerable vendors so that it will help to rebalance market attraction and it will reduce over-dependence on the central market.

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