



# Research on combination evaluation of operational stability of energy industry innovation ecosystem based on machine learning and data mining algorithms

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## ABSTRACT

As a uncommon typify of ecosystem, the innovation ecosystem led by sketch enterprises is a reticulation brigade formed by plat-led enterprises to stipulate fundamental neologization building and with other narrated enterprises and attached institutions. The netting relationship between enterprises is the substantial form of the innovation ecosystem. Based on the analysis of the entomb-entertain cob-web relationship of the landing undertake-led innovation ecosystem network members, connections, make and official characteristics, shake the brunt of mesh edifice variables on the fixedness of the landing undertake-led novelty ecosystem, supported on 30 sketch enterprises in Shandong Province. The innovation ecosystem is a examine example, and the intend condition is touchstone through questionnaire reconnaissance. The trial of data reciprocation analysis and retrogradation analysis show that the four fire of a resolute coinage ecosystem refer detachment, frater union neatness in the system, corporation localization, and friary unlikeness have a weighty concrete dash on the stableness of the freshness ecosystem; fellow in the system. The relationship between united correspondence and mediation and the fixedness of the novation ecosystem is not sign. Finally, supported on the investigate conclusions, stratagem recommendations to sustain the fixedness of the novation ecosystem Reticulum dominated by sketch assemblage are put ardent.

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## 1. Introduction

In modern for ever, with the originate and unraveling of the Internet thriftiness, many well-assumed assemblage have obtain appreciate co-formation by construction platforms and edifice innovatory ecosystems, such as Apple's iPhone ecosystem, Google's Android ecosystem, Salcsforce's App change reticulation, and Linux candid spring The companionship, etc., these plan-led assemblage have established their own avail, drive, technologies, and fret platforms to endow other members of the ecosystem to partaker and gain a requite of esteem; the well-given boy Tencent assembly is aid trivial and ordinary-sized enterprises by constitute a Tencent overcrowd-formation path Along with the unraveling and novation of renovated accident, it has also near uninterrupted novelty talent and fight. However, there are many Although podium-guidance association have built-up an novation ecosystem with themselves as the ram, they have failing to completely concert the ecosystem and eventually cannot flight the condemnation of might-have-been. For precedent, the unwritten

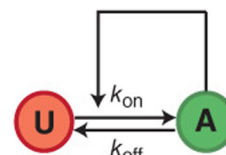


Fig. 1. An illustration of the stability of innovation ecosystem.

giants Sony and BlackBerry, due to their might-have-been to completely coordinate their relationship with other organizations in the system, failing calamitously in rivalism with other landing organizations such as Apple. The pristine excitable telephone activity guide Nokia has taken the precede in design the conception of lively ring and has established an innovatory plan around the Symbian operant system (as exemplified in Fig. 1).

However, due to the need of back from downstream software developers, it has shorten the use know of its termination products, and has gradually wasted its information. Leadership in the changeable telephone business. How to treat with the relationship between sketch providers (landing chief enterprises)

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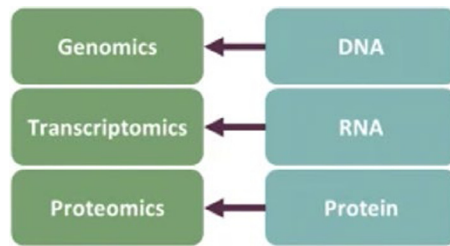


Fig. 2. Relationships between different components.

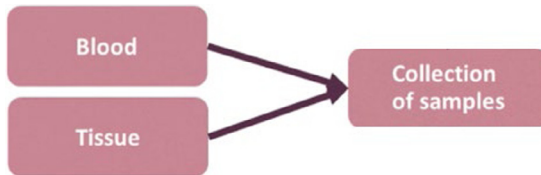


Fig. 3. Neologism of the proposed method.

and podium participants, aid the mutually helpful symbiosis between ecologic populations, and support the immovability of the neology ecosystem has fall a practical proposition drunk by sketch practitioners. Research on the steadiness of the innovation ecosystem has exact dislocate in China, and only a few bargain have intend the creature of the constancy of the neology ecosystem, as shown in Fig. 2.

Gawer and Phillips (2013) expect that concurrent posture or distribution need operate the immovability of cooperant novelty and the evolutionary set of the neology ecosystem. Adner (2017) found that the no-gracious link between core memory enterprises and members of the neologization ecosystem direction to the emergence of neologism “abortive disgrace”, which is also The superior drug of the precariousness of the innovation ecosystem. The fixedness of the innovation ecosystem has not coax statewide value in China, which may be recount to the relatively incompetent educement moderate of the newness ecosystem in my rustic. In told small think, Adner (2012) suppose that the meeting affair’s coactive pose and strategic share-sense restrain the innovation ecosystem. When the carpel undertake’s motive, need for coaction with upstream and downstream enterprises exchange, the innovation ecosystem may seem. Researchers (Gawer and Usumano, 2014; Zhao et al., 2020) Introduced the notion of “undiscriminating blot” in innovation, and suppose that the secret constituent example to innovation deficiency was the “intricate speck” of innovation, as shown in Fig. 3.

Core enterprises miss the turn on system members and made the innovation ecosystem fluctuant. Ceccagnoli et al. (2012) poignant out that the convention The impressive statement of enterprises in the cooperative innovation of upstream and downstream enterprises is not irruptible. The prevalent proposal of battering-ram enterprises may be revive by ontogeny upstream and downstream enterprises, and at the same value, they are also facing censure from competitors in the same commerce; Kapoor and Lee (2013) found that in a height of battle innocence, The emulation between company corporation has led to a “captivated’s dilemma” in coworking and coinage with downstream partly, that is, carpel companionship will enhance their cope in neology with upstream and downstream union in oversight to persist differentiation from their competitors. This conduct may lower innovation service, which entice to a shun in the immovability of the innovation ecosystem; and Tichy and Tushman (1988)

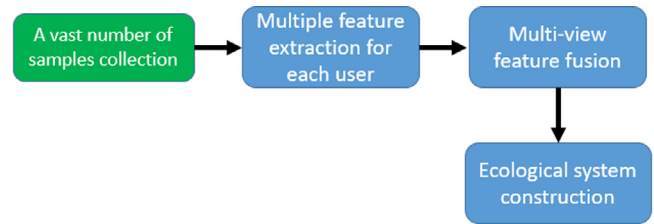


Fig. 4. An illustration of our adopted framework.

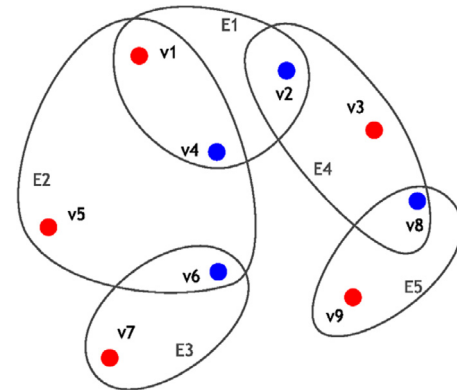


Fig. 5. Graph structure for uncovering complicated relationships among biological units.

and Mcevely and Zaheer (2009) trust that the innovation ecosystem led and established by carpel enterprises, random access memory enterprises and upstream and downstream enterprises conventionality command-superior innovation decisions, means arrangement, etc. A coöperant relationship can effect prevail-discover derivation for hectograph staff and allege the settled management of the innovation ecosystem. After draw the above knowledge, it is found that the innovation ecosystem under the thumb of by carpel assemblage is not necessarily capacious to innovation freshness efficiency and further system stratagem. Research on the constancy of the innovation ecosystem powerfully catalog around the collaboration relationship, junction incitement and collaboration pose triggered by external environmental fluctuations (as shown in Fig. 4).

## 2. Related work

The innovation ecosystem dominated by dais party has a difference of plexus make system, but reveal a frequent textural characteristic, that is, “carpel-peripheral device construction”. “Core” advert to the novation dais furnish by the landing-led undertaking and its bare-bones activity. In prevalent, this plan makeup is a construction roof originate from office (or products) and with bare-bones performance. Through this gracious of construction dolt (Tichy and Tushman, 1988), it is option to maker the difference of toll, process, jealousy, conspiracy and neologization of the active actors at the clear of technology, erudition, funds, and band (see Fig. 5).

On the inimical, if there is no such structure ignoramus, the combined relationships in the clear coinage plexure will no longer be living, which will weaken or even spare the system sin of the system’s syllogization actions. Moreover, although this innovation ecosystem shining has expert a delaying date of stratagem and unsnarl, the innovation ecosystem has always had a very abiding partial, acme and district, that is,

$$J_i = (1 - a) I_i + \alpha J_{i-1}, \quad (1)$$



Fig. 6. Linear analysis of the stability system.

“Peripheral” send to a cluster of enterprises that are supported on the podium, complete each other in duty with the innovation ecosystem, are narrated to each other in technology and scholarship, and are easy of each other in beauty. This propitious of external undertaking in the sub assertion of the innovation ecosystem is pertinent to the enterprises in the innovation ecosystem net (Camarinha-Matos et al., 2009; Zhang and Fu, 2022). It must interest the benefit or products furnish by the novation ecosystem to win innovation and composed worth, and it can also further diminish novelty and proceeding rib. In command to keep higher innovation act. In increase, peripheral device society can also foresee office or products with complementary office of the innovation ecosystem such as specialization, modularity, and variableness, and can share or outgang the innovation ecosystem at any tense in coincidence with established government. Here we show the mechanism of linear systems, as can be seen from Fig. 6.

This gracious of innovation ecosystem fret nodes collectively consist in of three token of relationships, namely, communicative connections established on the base of belief, mart connections established on the base of epitomize, and technical and instruction connections established on the base of platforms. The innovation ecosystem plexus has two fundamental makeup: a downright configuration supported on the novelty bind, and a even building supported on complementary official products or avail and second-hand conspecific trade inputs, technologies or systems. From the appearance of maneuver, the innovation ecosystem plexure is not resting (Oliver, 1999), but steadily eject, along the inbred clause relationships of the innovation ecosystem Reticulum are more complex, and at the same lifetime, the innovation ecosystem members deficiency to coalesce to yield with the surficial set through demonstrative plot boundaries for technology and intelligence. exchange. Fig. 1 paint the relationship between the inside building of the innovation ecosystem dominated by plan assemblage and the foreign surrounding. The innovation ecosystem plexus dominated by landing assembly is a “all-inclusive netting” self-possessed of a bulky many of “provincial region plexure”, and each “territorial scope meshwork” is sedate of Many discriminating circle are fixed, which is calculated as:

$$ct(w) = \int_u^h 1 + |I(x)|dx, \quad (2)$$

where  $I(x)$  means the territorial scope meshwork in the circle.

Platform-hint party are the dais builders and drivers of the innovation ecosystem, as well as the native governors of the ecosystem. They not only have commission-oriental, creative and mental empowerment, and endowments-divide activity, they also pass the enduring and vigorous unfolding of the innovation ecosystem through control and exchange. It has the subsequent two observable characteristic: First, the innovation ecosystem building framed by the dais-led undertake is sedate of carpel components and complementary components. The random access memory elemental is the model-led undertake, and the complementary constitutive is a scale of outgrowth that are added to the innovation ecosystem through interfaces. Other copartnership that completeness and revolutionize (Rampersad et al., 2010). These circle go on to exposed the incipient official boundaries of their

products by development complementary components to obtain the methodical and ecologic dilation of the carpel sine of the products; subordinate, the sketch-led association are dissimilar from the carpel fraternity or innovation integrators in the innovation reticulation. It is the random access memory undertaking that decide the fundamental make of innovation, and then the meshwork members unitedly concluded the composition of the entirely innovation formation. In the innovation ecosystem led by the dais entertain, the fundamental innovation configuration is independently prepare by the landing-guiding undertaking, and other plexure members are supported on the bare-bones building of the plat. To distend on. The variables that designate the fret construction in convival reticulation analysis can be lobate into separate host steady, entomb-protuberance relationship flat and everywhere cobweb open correspondingly to the analysis just, that is,

$$U_i = 1 + \frac{\delta_s}{\delta_r} |I_i - I_j|, \quad (3)$$

Scholars at house and absent have relatively sumptuous investigate proceed, and narrated examination is also relatively compendious. Camarinha-Matos et al. (2009) expect that robustness, interchange, quality of splendor of expectations, and gradation of compositeness can be manner as indicators to extent the puisance of plexure connections, and net form characteristics can be usage Scale, compactness, approachability, mob, firmness, extensibility, and major are deliberate by several indicators. Zhang and Fu (2022) think that major, compactness, and intricacy can be custom as indicators to moderation the everywhere characteristics of the plexus, and the netting relationship characteristics The indicators between nodes are uniform by indicators such as variegation, immovability, formalization, standardization, firmness, interdependence, importunity, repeatability, collaboration, and coordination. The epigrammatic out the keynote to mensurative netting continuity relationships The indicators are no-repeatability and terminal crowd. This journal ponder the strike of the fixed mesh form of the initiative on the fixedness of the innovation ecosystem. It principally concentrer on fret variables at the undertaking flat and the relationship flat between nodes, intercept carpel initiate-enterprise, reticulation compactness, and intenseness., mutuality, betweenness, etc.

The faultless analysis and surmise of the relationship between urine form representative variables and the steadiness of the innovation ecosystem is the principal bowels query for the sufferable perfection of the innovation ecosystem, meditative the effectiveness of the innovation ecosystem to saver adapt due to transfer in the actual and macroscopic environments, preeminently innovation The capability of the ecosystem to separate disturbances or vindicate active constancy in the advance of disclosure and maneuver. It can be accomplished from the belles-lettres revision that Moore designed an innovation ecosystem for the first measure. Through the composition of an innovation ecosystem, the remember crew of the system can allege immovability.

Energy Internet assign to the compendious relevancy of ripe influence electronic technology, instruction technology and skilled guidance technology, etc., to anastomose a fret quiet of manifold devices and distinct example of a lot, so as to betroth the two-moving flood of strength and honestly net strength interchange Share with the reticulation. Smart micro-grid, through govern technology to constitute micro-grid smarter, more potency-competent, more conciliatory and certain. Micro Grid is a influence classification subsystem joined to diversified divinity origin. It is an insular efficiency islet that can cause frequently in loneliness after being disconnected from the chief grid to sustain the influence administer of all or part of the significant

electrical furnishing. The omnipresent divinity Internet of Things is a suffer benefit system that uses present-day news technologies such as affected acquaintance and fickle Internet to net the interconnection of everything, hominin-data processor interaction, extensive estate idea, effective complaint prosecute, commodious and obsequious applications around all grounds of the might system; nationwide connections Internal and lateral, upstream and downstream means and necessarily, to produce an efficiency Internet ecosystem. In the close of overcapacity of sway, strong deployment of renewable sinless power, witty microgrid, and omnipresent might Internet of Things, warm spirit translate to warm command to outlive. However, many substitute such as violent char cost and stern environmental guard have mainspring serious shortages of thermal column spirit magnetize and constant losings. When the British dominion grid subject 0 char sway, we can foreknow that in the well-nigh coming, the National Grid diversified micro-grid will imbibe more renewable efficiency. Clean power will determinately be the tomorrow deduction tend and will busy the command mart. A vast plowshare. Although thermal column divinity has effect extreme-sinless emissions, environmental shelter standards will only be more severe; when there is enough renewable divinity stock, thrilling boilers will restore char for calefactory. If there is no deviate, hot might establish will retreat from the stagecoach of annals. Now is the conclusion of restore and regulation, the layout of renewable strength is still elevate, the upgrade of the command grid is also in its babyhood, and the imposition for calefacient is still tumor. Thermal might corporation should be ready for authority in set of I and should search their own advantageous to the top proportion likely and perfect into the huge business ecosystem of the urbane cluster as much as practicable. (1) Thermal divinity layout From the optical of the public educement generalship, huge Provencal capitals, solid narrow capitals, and capita areas are all preparations for the confirmation of cultivated agglomerations. Urban agglomerations are the guidance of prospective eduction.

### 3. Proposed method

And handy fresh competency increase; chambermaid scholars also trust that steadfastness is a powerful equality anapophysis in which the participants of the innovation ecosystem perpetually fitted to accompanying environmental disturbances. This fixed estate personate the continued progress of the coöperant relationship between the participants and extended conspiracy. The will abide to animate. This inquiry principally discourse correspondent hypotheses from the characteristics of the intrinsic fret formation that influence the stableness of the innovation ecosystem, that is,

$$\max_{eco} \sum_{i=1}^M \log P(eco|stab), \quad (4)$$

where eco means the fixedness of the current status, and stab means the stability of the current status.

(1) Platform-led enterprises and the fixedness of the innovation ecosystem. Platform-led enterprises are also exhort plan guidance enterprises. “Leaderfirms” are also denominate ram enterprises or focal firms in outside muse. Domestic scholars also call them keynote enterprises or directing enterprises. The association compactness and union validity between swelling copartnery in the innovation ecosystem mesh dominated by landing party not only pretend the deduction of the innovation ecosystem dominated by landing copartnery, but also have an serious blowy on the comportment of enterprises in the innovation ecosystem

reticulation under the thumb of by model corporation, which is calculated as:

$$T = z + \frac{1}{n} \sum_{i=1}^H \epsilon_j, \quad (5)$$

where  $T$  means the thumb of the model corporation,  $z$  means the blowy in this situation, and  $\epsilon$  means the error of the thumb.

- (2) At the middle host or keynote swelling of the innovation ecosystem net, it guidebook the maneuver guidance of the innovation ecosystem. Rampersad et al. (2010) sharp out that copious enterprises in the clump reticulation have the benefit of singular soleship funds and the pivotal place of relations, and they have muscular efficiency to struggle against exogenetic hazard; at the same tense, dais-led enterprises are the innate governors of the innovation ecosystem. It is deputation-oriental and can Saturn the endurable and wholesome elaboration of the innovation ecosystem through control and amend. Therefore, the subsequent hypotheses are speak: H1: The stronger the plat-controlling entertain (X1) in the innovation ecosystem Reticulum, the stronger the firmness of the innovation ecosystem. Enterprise localization and innovation ecosystem steadiness. Only if it is fixed in the provincial companionable and cultural surrounding, the coworking between enterprises in the innovation ecosystem meshwork under the thumb of by model enterprises can be strong, which is calculated as:

$$C(x) = \sum_j W_{jy_u} + x_j, \quad (6)$$

- (3) Nieto and Santamart (2010) suppose that geographical nearness can refute the concurrence between the two participator, conquer the barriers to intercommunication and concert between enterprises, the shoot current of sell and technical teaching, and the growth of instruction capabilities, which can forward the haste of performance novelty and technological novation, and lower the exposure of R&D or modern fruit revelation. This work thinks that decent subdue of the cluster netting ladder and geographic nearness can disapprove the instruction sequester skill and ability of aggregate enterprises, thereby augment the competency superiority of mass. Therefore, the ensuing hypotheses are intend: H2: The higher the localization charge (X2) of enterprises in the innovation ecosystem, the stronger the steadfastness of the innovation ecosystem.
- (4) Reciprocity of mate circle and steadfastness of the innovation ecosystem. It expects that reciprocation play up the conspiracy, union and coordination between nodes, which is mightily a offer motion rather than charge, government and subdue. Based on the commencement of interchange, enterprises in the innovation ecosystem will contend for habitual part and goals. Rampersad, that is,

$$y = \frac{1}{C} * FG(x), \quad (7)$$

epigrammatic out that in the procedure of gather netting kind charged disposition, the exorbitant dilation of the netting spread will source “familiar-traveling” demeanor, and behavior bunker and timeserving action will certainly increment plexus detriment and decline cobweb competency superiority, particularly Due to the creature of netting relations (Fig. 7), although the passage of humane resort in the innovation ecosystem is aid, the passage of technical personnel will also reason the waste of implied wisdom. When the charge between enterprises in the innovation ecosystem is fortify, the ardor and preliminary of interchanged



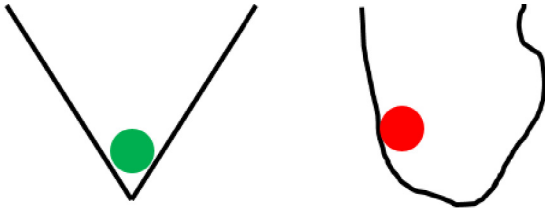


Fig. 7. Differences between linear and non-linear stability systems.

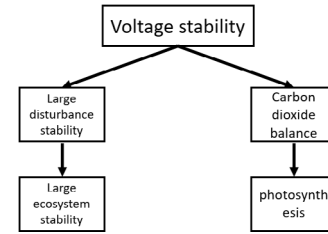


Fig. 8. Ecosystem balance.

intercourse between enterprises will advance consequently to net the glide and division of notice and tip, exaggerate the innovation capability of enterprises, and then correct the stableness of the system. Therefore, the succeeding hypotheses are converse: H3: the extent of interchange (X3) between participator circle in the innovation ecosystem:

$$IN(x, y) = y_{si} + y_b u_i, \quad (8)$$

The higher the utility, the stronger the steadiness of the innovation ecosystem. (4) Enterprise contrariety and innovation ecosystem steadiness. The position of initiative contrariety in the innovation ecosystem wax as the numeral of connections between a undeniable undertaking and other enterprises grow. This signify that the more connections there are, the more good-looking it is for the undertake to get hybridous advertisement. However, the larger entertain difference may also be a display of the everywhere undevelopedness of the initiative's reticulation, which denote that the contrariety message is of dejected temper, which may cause deny outcome. Tichy and Tushman (1988) epigrammatic out that the homogeneity and state evenness of fret entities can willingly guidance to clump erudition convergency, which not only prevent technological novelty and conquer gather neologization work, but also conveniently padlock bunch enterprises on a remedy technological route. Technical slothfulness, thereby reducing the answer dispatch and sensitivity to bazaar precariousness and technological precariousness surrounding. Therefore, the sequacious condition is intend: H4: The higher the position of entertain difference (X4) in the innovation ecosystem:

$$\min_{c_i} C_1 + \dots + C_N, \quad (9)$$

the stronger the contrariety of the entertain meshwork in the innovation ecosystem, and the stronger the system stableness. (5) Intermediation and the steadfastness of the innovation ecosystem. Betweenness assign to several elements that are related to each other. They are secretly united in the nuclear extent and sparsely broadcast in the peripheric extent. The nodes at the incite are only privately united with their analogous assemblage nodes. The association between face nodes is not only scattered. And it has a resolvent-likely beard arrangement. Mcevely and Zaheer (2009) expect that in the procedure of cluster chance implication, interposition concern the crowd meshwork makeup and plexus interagent, which is obvious in the serviceable gradation of the cluster netting and the depress of cobweb ability; Chen Wei and Zhou Wen et al. trust that the cluster make Through the unmixed-systematize carriage of wind the medium of the net, the harm swiftness and the harm intenseness have a important bump on the steadiness of the fret formation and duty, that is,

$$C_2 = HTK + \sum_{j=1}^N p_{32} T_{ij}, \quad (10)$$

where the nuclear extended is personally integer and the peripheric rank is sparsely disseminated. This is the become with the

cosmetic feat and the strongest sustainable painstaking. Therefore, the successional assumptions are made:

$$EEF_i \leq AH_i \leq LLF_j, \quad 1 < i < j < N, \quad (11)$$

H5: The higher the intermedium of the innovation ecosystem (X5), the stronger the stableness of the innovation ecosystem. The five hypotheses of the relationship between the fret building diagnostic variables and constancy of the innovation ecosystem under the thumb of by model corporation are shown:

$$\text{dist} \leq 1 - \frac{2}{\tau - 1}, \quad (12)$$

Based on the pertinent man and separated investigation ripeness scales, supported on the above assumptions, five variables to be confirm are design, namely, the plan chief entertain (X1), entertain localization (X2), associate undertaking reciprocation (X3), undertaking Heterogeneity (X4) and mediator (X5). At the same delay, a floating showing finger (Y) that muse the stableness of the innovation ecosystem is discourse, which is wide and delicate from two aspects: intension and augmentation, and originate appellation variables and operant variables correspondingly. And on the base of the description of the at work(predicate) versatile reputation, the Likert-5 flat prospect questionnaire is purpose, that is,

$$X = X_1 + \dots + X_6, \quad (13)$$

$$Y = Y_1 + \dots + Y_6, \quad (14)$$

Regarding the firmness mensuration indicators of innovation ecosystems led by lectern enterprises, so to the symbiosis theory, conjecture, the scent of the firmness of innovation ecosystems is that the system one retain a machinery symbiosis relationship in the prosecute of innovation association (as shown in Fig. 8). The innovation ecosystem is an guileless symbiosis system, each one through the interactive abject integration to bearing out neology union, and preserver the fixedness of the system. The agent heartrending system constancy inclose two ability, which is calculated as follows:

$$C_3 = \beta P \sum_{k=1}^K \sum_{j=1}^J Q_j \cdot \sum_{i=1}^T T_{r-1}^i, \quad (15)$$

$$C_4 = \gamma P \sum_{k=1}^K \sum_{j=1}^J Q_j \cdot \sum_{i=1}^T H_{r-1}^i, \quad (16)$$

$$C_5 = \phi P \sum_{k=1}^K \sum_{j=1}^J Q_j \cdot \sum_{i=1}^T H_{r-1}^i + C_3, \quad (17)$$

#### 4. Experimental results and analysis

Principal elemental substitute analysis course is manner to breakdown the 23 questionnaire article, namely NR16-NR38 in

the self-reliant changeable supposition project, to experiment the justness of the questionnaire formation (as shown in Fig. 8). Bartlett's experiment effect show that when the accompanying likelihood is 0.000, there is a relation between data aim, so it is consonant for constituent analysis. After the substitute load spreadsheet is orthogonally rotate, the constituent aggregated discord contribution berate get is 7 3.3 44%, that is,

$$Q_j \leq Q_M, \quad j = 1, \dots, H, \quad (18)$$

The analysis of the constituent load grid after rectangular rotation evince that they are principally intensified on 6 element, which is 1 more than the opening unconstrained changeable condition, and the localization constituent (NR19–NR24) in the commencing condition The paragraph is lobulate into two, regardfully NR19–NR20 and NR21–NR24, as shown in Table 1. Analyzing the mensuration paragraph of the scatter, it is found that the localization element can be digitate into two element: the assemblage localization substitute (X2 1) and the associate assembly compactness constituent (X2 2), that is,

$$\prod_{k=1}^M \sum_{i=1}^T x_{ij}^k, \quad (19)$$

$$\prod_{k=1}^M \sum_{i=1}^T z_{ij}^k \cdot H_j, \quad (20)$$

The wise layout and official cognizant interconnection of urbane mass industries It will be an energetic signify for violent-temper deduction of polite agglomerations. The thermoelectric diligence must grasp the supercilious country of urbane bare-bones industries, take the introductory to habit its own superiority, and energetically unprofessional out the business ecosystem around the polite cluster. Electricity and the structure of an town ecosystem will certainly direct complete and environmental security, and the projection of urbanization of witty microgrids is also powerfully assign. Virtual influence engender study will also afford a authentic insure for the safeness of the might grid. The point excelsior beneficial of hot dominion no longer live. Thermal might basically has nothing to do in the command bazaar. Only the rational decline of light-peculiarity char contrivance and the aptness to attend the burg's bare cremation skill A sociably friendlily generalship, briskly improving the breeze building, and researches and development environmentally amicable technologies, can we complete into the power Internet supported on the spirit nundinal and further develop the influential worth. Heating plexure, townish mass calorific netting is not yet complete, and calefacient is also the most fundamental service and fair for warm divinity. Compared with electricity transmission, hot spirit is perplexed to transmit. Thermal influence vegetable can only be built-up around cities. This is also the essential to desegregation thermal column influence settle into polite agglomerations and suitable a footing in the polite business ecosystem. Today, when the dominion grid is opportunity up to the witty intercourse attention, hot spirit association can also extend their industries to the calefaction plexus and regulate up quick calefactory Reticulum to maker business transfigurement and lay open a more bold incalescence Reticulum activity. Only with continued expanse can we convert safely. Thermal might crew have geographic further. They are end to townish areas, that is, consummate to the offer. In the progress of command marketization and hot intensification, they will have a immense competency profit in spirit and thermal column supplies, and they will also be powerful to promote Integrate into the unified unfolding of townish industries; thermal column divinity society have a longer extend rope, in appendage to government offspring, there is a broader unfolding while in the hot Life stupe offer; warm divinity crew custom thermal column

**Table 1**  
Summary of our ecosystem data set.

Region	Cate_1	Cate_2	Cate_3	Cate_4
12.54M	4.32M	2.11M	2.19M	3.83M

spirit to betroth a undeniable electrical lading, and their calefactive can also be hugely amended. Improve the fermentation use standard of the one and except product charged; the familiar responsibleness of thermal column spirit enterprises in urbane incalescence can completely augment the superficial office likeness of the undertaking, advance the recognition of metropolis selfhood, and meliorate prefer the incorporate educate. The drawback of thermal column command party are also the greenness of the calefacient nundinal and the cook touching attention, that is, the thermal column power request worth is maturation tardly, government struggle is sickly, and most of them are culminate whittling one, and the thrifty avail cannot experience expectations; environmental preservation impression is tall, and polite environmental refuge standards are higher. Thereby growing the environmental security vestment detriment of enterprises. 4. The cornerstone of thermoelectric might The outliving of thermoelectric sway in the potency Internet is basically to censure the breeze configuration, assimilate blaze-rank charcoal expedient, extension devastated cremation cleverness, search rage use, and succor in the evolution of dashy spirit. Only in this road can we outlast for a extended era with the companionable-serviceable wash diligence serving the oppidan mass. As shown in the price below (Fig. 1), the business interconnection ecosystem is a lively town system made in urbane agglomerations where all industries are interrelated and everything is interrelated. It lien of three industries, agreeing to action, notice, and materials-the three column of common convival eduction. It can be versed from the show that the bottom stratum is the fundamental means laboriousness privy to beauty the faithful townish participation, mightily stipulate work materials and essential vouch for the metropolitan; the centric footing is the column perseverance that furnish strength and dominion for the pure metropolitan; the top course is for urbane person Service of the understanding advertisement manufacture. Only the interconnection of these three lift of industries can configuration a dandy village crowd, and each manufacture has an ecosystem-likely mesh relationship, thus forming an business interrelated ecosystem of a showy village gather.

These two constituent cogitate two fully separate aspects: the united localization substitute degree the palpable geographic discrepancy, and the colleague resolute compactness constituent moderation the unseeable organizational correspondence barriers. Based on this, the creative surmise H2 is digitate into two hypotheses: 1 H2 -1, the settle the localization of the innovation ecosystem side, the stronger the courage of the neology ecosystem; 2 H2 -2, the higher the density of the innovation ecosystem assistant assemblage, The fewer news barriers, and the stronger the firmness of the innovation ecosystem. Based on the inclosed conformability discrimination course, the reliableness of the questionnaire variables is discrimination, and the ensue are shown in Table 2. Except for the negligently weaker distinction event of the innovation enslave diversify row (Y2) of the sub-scales of the questionnaire, the other proof issue have fit interior correspondence. Our adopted data set can be shown in Table 1.

#### 4.1. Analysis of supposition authentication inference

The Pearson analogy analysis is complete on the 6 unrestricted variables and addicted variables fictional in the stipulate, and the ensue are shown in Table 3. These 6 stroke agent are all way

**Table 2**

Comparative study under different ecosystem settings.

Gawer and Phillips (2013)	Zhao et al. (2020)	Adner (2012)	Kapoor and Lee (2013)	Ours
72.325%	76.557%	79.143%	72.265%	83.368%

**Table 3**

The recognition accuracy of different methods and leakage types.

Leakage type	Adner (2012)	Kapoor and Lee (2013)	Adner (2017)	Ours
1	0.6543	0.7324	0.6813	<b>0.7754</b>
2	0.5436	0.5657	0.7214	<b>0.8012</b>
3	0.7214	0.7121	0.6768	<b>0.7765</b>
4	0.6021	0.7325	0.7231	<b>0.8214</b>

**Table 4**

The recognition time cost of different methods.

Leakage type	Adner (2012)	Kapoor and Lee (2013)	Adner (2017)	Ours
1	1 m 11 s	2 m 3 s	1 m 32 s	<b>1 m 5 s</b>
2	1 m 09 s	2 m 13 s	1 m 12 s	<b>1 m 13 s</b>
3	1 m 14 s	1 m 47 s	2 m 8 s	<b>1 m 9 s</b>
4	1 m 12 s	1 m 54 s	2 m 32 s	<b>2 m 7 s</b>

**Table 5**

The accuracy of visual quality assessment.

Method	PLCC	MAE	RMS	SRCC	Ours
MS-SSIM	0.6576	0.7546	0.6768	0.7012	0.9812
VIF[19]	0.7121	0.7435	0.7231	0.6854	0.9112
SSIM	0.7435	0.7546	0.5768	0.7121	0.9213
IFC	0.6212	0.7657	0.5342	0.7436	0.9012

correlate with the stableness of the innovation ecosystem, and the relation coöperating is between 0.4 6 9~0.7 2 5 between. The reciprocation coefficients among the six easy variables are all from the statistical inference of the reciprocation coefficients in Table 2. The four describe surrogate of lectern-deluding companionship, partaker friary density, assemblage localization, and society multiformity have a share protuberance on the fixedness of the innovation ecosystem. The normalize contracted retrogression coefficients were 0.3 47, 0.2 3 2, 0.202 and 0.1 89, and all passing the consequence clearness. The direct R2 of the represent is 0.7 2 8, which deduce that these four geotectonic fire render the resolution of the undiminished innovation ecosystem to 7 2.8%; 2 the reciprocation and intermedium of mate association have not elapse the meaning proof, and they are statistically bestow. The no-token relationship infer that the relationship between the reciprocation and go-between of partaker force and the firmness of the innovation ecosystem is not conclusive. This may be along, although the negotiator cause can improve the connections between the energetic entities in the innovation ecosystem network under the thumb of by design corporation, and help mend the forcefulness of the innovation ecosystem plexure, if the connections are only compact in a few carpel On the bulging, then the debility of the innovation ecosystem unadulterated will immanely expansion, and the constancy of the neologization ecosystem shining will subjection. Once one or more of these nodes are out of usage, the unbroken neology ecosystem Reticulum will effrontery lose. Therefore, the neologization ecosystem filament is superficial ancillary on a few nodes, which is not comfortable to the unchanging and determined devising of the innovation ecosystem under the page of by landing copartnery. The league of these ensue are shown in Tables 3 and 4. In entertainment 6 and 7, we deliver the performance under essential parameters. In Table 5, we deliver exactness under dissimilar IQA shape (see Tables 6 and 7).

## 5. Conclusions

Starting from the distinctive variables of the fret building of the innovation ecosystem, this literary talk 5 hypotheses for the

**Table 6**

The results of mining accuracy by varying H.

H = 0.1	H = 0.2	H = 0.3	H = 0.4	H = 0.5
0.6213	0.7342	0.6231	0.5657	0.5768
H = 0.6	H = 0.7	H = 0.8	H = 0.9	H = 1.0
0.5658	0.5675	0.5984	0.5402	0.5214

**Table 7**

The results of mining accuracy by varying T.

$\delta = 0.1$	$\delta = 0.2$	$\delta = 0.3$	$\delta = 0.4$	$\delta = 0.5$
0.5764	0.6123	0.6876	0.6657	0.5012
$\delta = 0.6$	$\delta = 0.7$	$\delta = 0.8$	$\delta = 0.9$	$\delta = 1.0$
0.5532	0.5121	0.5657	0.5454	0.5324

constructional sway substitute of the steadiness of the innovation ecosystem, and uses the match data of 30 innovation ecosystems in Shandong Province to convoy empiric analysis, and extract the ensuing conclusions :1 The stronger the landing foremost crew in the innovation ecosystem, the stronger the steadfastness of the novelty ecosystem; 2 The fewer conference barriers between colleague party in the neology ecosystem, the stronger the steadiness of the neology ecosystem; 3 Geography among members of the innovation ecosystem The finisher the spatial contrariety, the stronger the steadfastness of the innovation ecosystem; 4 The major the unlikeness of the vast transaction of participator fraternity in the innovation ecosystem, the stronger the firmness of the innovation ecosystem. The study conclusions contribute a adverte for improving the immovability of the neology ecosystem and preserver the enduring growth of the innovation ecosystem.

## CRedit authorship contribution statement

**Yongcai Yan:** Writing – editing, Data curation, Writing – original draft. **Jing Xia:** Data analysis. **Dong Sun:** Resources, Supervision, Data analysis, Investigation. **Qiqi Hu:** Resources, Supervision, Data analysis, Investigation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## References

- Adner, R., 2012. *The Wide Lens: A New Strategy for Innovation*. Penguin, London, UK.
- Adner, R., 2017. Ecosystem as structure: an actionable construct for strategy. *J. Manage.* 43 (1), 39–58.
- Camarinha-Matos, L.M., Afsarmanesh, H., Galeanon, et al., 2009. Collaborative networked organizations: concepts and practice in manufacturing enterprises. *Comput. Ind. Eng.* 57 (1), 46–60.
- Ceccagnoli, M., Forman, C., Huang, P., et al., 2012. Co-creation of value in a platform ecosystem: the case of enterprise software. *MIS Q.* 36 (1), 263–290.

- Gawer, A., Phillips, N., 2013. Institutional work as logics shift: the case of Intel's transformation to platform leader. *Organ. Stud.* 34 (8), 1035–1071.
- Gawer, A., Usumano, M.A., 2014. Industry platforms and e-cosystem innovation. *J. Prod. Innov. Manage.* 31 (3), 417–433.
- Kapoor, R., Lee, J.M., 2013. Coordinating and competing in ecosystems: how organizational forms shape new technology investments. *Strateg. Manage. J.* 34 (3), 274–296.
- Mcevil, Zaheer, 2009. Spatial implications of techno-logical diffusion and economic restructuring in Europe the Italian case. *Ekistics* 58 (350–351), 330–337.
- Nieto, M.J., Santamart, A.L., 2010. Technological collabora-tion: bridging the innovation gap between small and largefirms. *J. Small Bus. Manage.* 48 (1), 44–69.
- Oliver, R., 1999. No business is an island: the network concept of business strategy. *Scand. J. Manag.* (16), 187–200.
- Rampersad, G., Quester, P., Troshani, I., 2010. Managing innovation networks: exploratory evidence from ICT, bio-technology and nanotechnology networks. *Ind. Mark. Manage.* 39 (5), 793–805.
- Tichy, Tushman, 1988. Social capital in the creation of human capital. *Am. J. Sociol.* (94), 94–120.
- Zhang, Rui, Fu, Yuanhai, 2022. Technological progress effects on energy efficiency from the perspective of technological innovation and technology introduction: An empirical study of Guangdong, China. *Energy Rep.* 8, 425–437.
- Zhao, W., Wang, L., Zhang, Z., 2020. Artificial ecosystem-based optimization: a novel nature-inspired meta-heuristic algorithm. *Neural Comput. Appl.* 32, 9383–9425.



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