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Psychometric Validation of an Open Source Software Development (OSSD) Scale in Indian Industries

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ABSTRACT

This study has taken a step toward developing and testing a psychometric scale to measure the practices of Open Source Software Development (OSSD) within industries in India, thereby addressing the absence of context-specific instruments designed for emerging economies. The study employed an empirical design consisting essentially of two phases, each tied to an established scale for the OSSD in the Indian context. In the first phase, Exploratory factor analysis (EFA) was used to analyse 480 respondents from organizations, while Confirmatory factor analysis (CFA) scientifically tested the two-factor, ten-item scale, which eventually appeared to have a strong model fit, doing justice to both the Product Speed and Product Quality dimensions of OSSD. In the second phase, this model was interval dated with external constructs Product Development Time (PDT) and Customer Satisfaction (CS) using a fresh test sample of 300 organizations. A very satisfying internal consistency and strong positive connection between each of the two dimensions difficulty and concerned performance outcomes are established, the total model variance being explained with 51% as noted on a PDT scale. This model draws the scope and construct validity, let alone the reliability of the instrument-that could measure OSSD. The model does not cast a very broad category to the generic innovation scale; whereas this kind of measure is exclusively to do with "open-source" developments such as objectives with distribution of activities, plan-to-make a development, and verily a community-implemented quality assurance. Thus, the present scale validation becomes significant being the very first in the setup of the OSSD universe in India for the purpose of offering a solid guide to researchers, policymakers, and practitioners on evaluating and supplementing OSSD performance within emerging market settings

Keywords: open source software development, product development, psychometric scale validation, innovation, product speed, product quality.

1.INTRODUCTION

The rapid progress of digital transformation has changed the way that software is being written, sold, and used all over the world in a very deep way. The Open Source Software (OSS) movement is the most visible part of this change, and it underscores the main ideas that have affected the software industry in terms of transparency, collaboration, and decentralized development paradigms (Li et al., 2024). The contrasts between the two models of development are striking, unlike the proprietary software model that locks in the developer community, the model of OSS attracts people from different organization types and locales to take part in the collective code development. This open, feedback-based process speeds up the pace of innovation, supports the element of surprise, and contributes to cutting down on the company's costs as well. The cost saving factor is only one aspect of the OSS argument (Griffin, 1993); it is a complete makeover of the way the firms see innovation – by switching from the traditional development, internally run processes to the trendy networked environment, and open ways, all being powered by shared brain and collective intelligence. The use of OSS in India has significantly increased in the last few years, especially among startups and organizations with limited resources, and researches indicates that the primary goal of the innovation licensing channels that are open is to decrease the cost of the software. In addition to that, Indian companies enjoy competitive advantages through exposure to the global developer communities, a variety of knowledge repositories, and community support mechanisms and now it is illustrated in a study that used anonymous examples of IT company visits and sought the views of professionals known to have experience in OSS (Von Krogh & Von Hippel, 2006). Moreover, the tremendous adaptability of OSS is one of the major reasons for the presence of tailor-made solutions to the linguistic, cultural, and infrastructural needs of India. The Indian technology sector, known for its dynamic and innovative entrepreneurial spirit, as well as cost-sensitive operational models, is a great place for OSS development to be studied, and its effect on the performance of innovation to be observed. With 100,000+ startup companies already registered and a rapidly growing software services market, India is a perfect place for investigating how open-source software development by companies in emerging markets such as India helps them gain a competitive edge. Despite all this, there is still a considerable number of Indian companies facing hurdles when it comes to including OSSD in the commonly used innovation and product development setups. Safety of IP, potential vulnerabilities within the open-source framework, and organizational objectives not being in line with open-source contributions have been some of the reasons for the slow acceptance of OSSD (Krishnamurthy & O'Connor, 2013). Even more of a problem is the fact that there is no validated tool that could measure in which way the organizations perform the OSSD practices and how it correlates with specific outcomes such as the speed and quality of development. This validation gap confines not only academic comprehension but also the practical application of OSS strategies in the contexts of India. In the absence of dependable measuring instruments, it is not possible for organizations to evaluate their OSS development capabilities systematically, the authorities cannot measure the impact of digital innovation schemes, and the researchers cannot theorize the dynamics of open-source innovation. The issue presented in this research is dealt with by the development and validation of a scale for OSSD that is specific to the context. The primary objective of the study is to assign a numerical value to the organization's performance in terms of innovative OSS-related products, which will be achieved through the two dimensions of the OSSD: Product Speed and Product Quality. Such dimensions were picked because of not only their theoretical implication in innovation research but also their actual relevance in software development cases. The Product Speed dimension represents the temporal effectiveness of product development processes, which is a crucial factor in competing in rapidly changing technology markets. Product Quality, on the other hand, is the total of the technical excellence and the functional effectiveness of what has been developed (Singh et al., 2024). This factor, in turn, not only determines the adoption by the user through time but also the reputation of the organization. These two factors align with the work done by Wang and Wang (2012), who considered speed and quality as the primary factors in an innovation process such as the one under a knowledge-intensive context. Nevertheless, this study has made room for a different set of dimensions by reshaping these concepts to suit the backdrop of open-source environments according to the present study, as it is based on the very same domains and is populated by new firms. The investigations are divided into two steps, each one applying a tough psychometric approach. The first step, using introduced and confirmed factors that will be the artifacts of the theoretical construct, proves the scale to be factorially valid. The second step observes the model in terms of its reliability, convergent validity, discriminant validity, and predictive validity against external criteria like the Product Development Time (PDT) and (CS) Customer Satisfaction. The latter section of the research work thereby with the help of a measurably stable and experimentally corroborated tool fabricated for the Indian innovation scenario becomes a part of the ever-expanding literature of OSS, and additionally, it offers practical instruments for industry professionals, policymakers, and investors to assess more accurately open-source development projects, thus benefiting all parties involved.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Open Source Software: Conceptual Foundations

The concept of Open Source Software (OSS) can be considered as a method of software development with the following characteristics: one can access and use source code, development processes are transparent, and it is the community of users that drives the product (Samdani & Afreen, 2024). This approach is completely different from the typical proprietary software approach where the source remains closed, and the development team works in the same organization (Hoffmann et al., 2024). OSS started its walk on the soil of collaborations, knowledge-sharing, and distributed problem-solving which all together call for rethinking the traditional notions of proprietary rights and the field of competitive struggle from where innovation also emerged (Goldmann et al., 2024). OSS also employs an innovative and highly productive method that is collaboration whereby the efforts of the distributed teams are pooled together to produce quality code. The omission of middlemen combined with thorough quality management makes OSS not only cost-effective but also the most efficient method of software production. The researchers further argued that OSS communities often possess the technical prowess to confront peer review and having encountered and dealt with the issues within the community, it is even likely that the project will have cleared certification before it is submitted for official testing and approval. The possible breakthrough of the OSS comes from a lot of interconnected loopholes. At first, the open-source code becomes traceable due to the increased size of human error and the many contributors or watchers that are constantly improving the code. Their test is larger than that of many commercial organizations, but not so big as to miss the specific incidents in the code. At second the group also has an easy platform and scalable operations, which makes the code a unified development matrix and easier to include the parts of the software that need further future development. In some cases, the absence of the barrier because of license fees leads to a wide-spread adoption and precludes the need for the competition in the commercial market. In this way, the competitive advantage is driven by the total product cost that can decrease from one offering to none rather than revenue models that rely on the high marketing and research costs and the monopoly demanded by copyright law. These mechanisms eventually put OSS software in a very good position to be used as a tool for doing a lot of new things. Startups and MSMEs have been the primary supporters of open-source software in India. They find above among the various attractions of this software the flexibility, cost-effectiveness, and the global developer community available all under one roof. The Indian technology environment has its own specific characteristics shaping the whole open software adoption track. One of the key factors is that the country has a very large number of skilled developers, most of whom have been trained in the computer science and engineering fields. They form the very basis for the country's effective participation in the international OSS community. The other side of the same coin is a very huge number of businesses in India that are very conscious of costs and hence very quick to adopt the use of open-source software where it is feasible. Also, the licensing fees for proprietary software have made the industry more fragmented into different segments and hence more varied in terms of software preference. Various government efforts to boost the digital transformation and homegrown technology have also been helpful in creating a market for OSS in public and private organizations. However, the transparency of OSS development brings in challenges in the form of security vulnerabilities, intellectual property protection, and coordination among organizations, which makes the integration of comprehensive evaluation mechanisms very challenging when assessing the organizational efficacy in managing open-source infrastructure.

Customer Satisfaction

The most crucial indicator of the success of the product and the effectiveness of the innovation in the marketplace is the satisfaction of the customer. From a theoretical point of view, CS is the integration of the innovation processes, product development and the internal development work that becomes the external approval of the market results (Nguyen et al., 2024). It reveals how development practices influence user perceptions and an organization's agility in incorporating the same in service quality improvement. The linkage between innovation processes and customer outcomes provides the most essential means for validating innovation measurement instruments because the scales quantifying authentic innovation capacity are expected to have a predictive power for satisfaction results. The validation of tools employed for customer satisfaction measurement has been through a significant change in their nature with the increase in service and technology contexts. In terms of innovation, customer satisfaction is the mediating result which is both dependent on the practices of product development and on the organization's receptiveness to the needs of customers. The organizations that have mastered the art of innovation fast track their responses to the changing needs of their clients and hence are able to provide quicker and therefore more satisfying service. The companies that are good in terms of innovation quality, in other words, that create the most reliable, effective, and advanced solutions automatically enhance the overall consumer experience and customer satisfaction. The foundation of the present study criterion validity evaluation is the theoretical relationship between OSSD factors (Product Speed and Product Quality) and CS. If the proposed OSSD scale does truly reflect the innovation competencies of the organization, highly scoring organizations would have better customer satisfaction outcomes. In OSS contexts, the customer satisfaction dynamics might be different from traditional, proprietary software, thus reflecting the nature of open-source projects. The organizations benefit from OSS capabilities most effectively if they can get the feedback either through the community-supported development process and act on it quickly or through the transparency of the open-source development where the customers can observe and possibly influence the development paths. The relationship between the OSSD scale dimensions and CS thus provides both validation evidence for the scale and insight into how open-source practices translate into market outcomes.

Product Development Time

One of the significant elements in determining the performance of technology is Product Development Time which is in reference to the temporal efficiency of making marketable products out of ideas. PDT is divided into several parts such as lead time (the total time of the initial request to the final delivery), cycle time (the duration of the individual stages), and time-to-market (the period from the inception of the concept to the market launch). These temporal calculations serve as the measuring stick for the efficiency of the development process and support the innovation capability subjective evaluations (Cooper & Sommer, 2016). In the modern software world, the use of PDT as an important metric for evaluating the organizational capabilities is common among the lean development and agile methodologies that are the main characteristics of contemporary software practices (Zheng et al., 2024). The shorter development times lead to organizations being more flexible in reacting to market gaps, introducing customer feedback into gradual improvements, and keeping their place in competitive technological environments. The consulting companies, such as McKinsey & Company, use PDT figures to compare their performance with the ones in the industry, so the companies have reference points for the organizational comparison. The universal implementation of PDT to show company performance indeed means that the performance indicators are of practical importance and that they measure an actual outcome. The linkage between the capabilities provided by OSSD, and the Project Development Time (PDT) is theoretically coherent and therefore demands predictive validity verification as an important factor in the field of new product development. The performance of product speed can be reflected as a main criterion to judge the performance of an organization as a supply chain or manufacturing enterprise. Faster product cycle time and more features per cycle means more productivity and a larger market share, to an extent where there is no need to spend a lot on marketing. This product speed factor becomes the start of a chain reaction that results in competitive advantage.

Diffusion of Innovations Theory

According to the Rogers (2003), the Diffusion of Innovations Theory illustrates the movement of new concepts, technologies, and practices in societies. The theory mentions certain significant features that slow down or speed up the pace of adoption like the following: the comparative advantage, compatibility, complexity, trialability, and observability (W. Li & Liu, 2025). The OSS (Open Source Software) systems are the ones that heavily rely on the principles of diffusion especially because of the qualitative and observational transformation done by community contributors who can try, observe, and gradually connect with the open-source projects. The transparent and open-source characteristic of OSS also contributes to the high burstiness in the model because it can easily be observed through the observability of the growth phases of the OSS project, and this gives the potential adopters the ease to measure community and project quality before getting involved. Diffusion theory concerns more the individual adoption decisions and the diffusion of innovations in populations, rather than the organizational performance level on managing innovation processes (Mbatha, 2024). This research places a special emphasis on the organizational ability to be successful in the case of OSS engagement and not on the paths of adoption across the populations. It is known that in terms of OSS approaches, enterprises often go through the same path as the early adopters. However, they still face a different set of the quality bug. They do not become the new early adopters and change their way of dealing with quality issues. The proposed OSSD scale is, in particular, built with an aim to provide complementary tools to the diffusion perspective to evaluate organizational performance once OSS adoption has occurred and it quantifies the two dimensions such as **Product Speed** and **Product Quality** that influence development effectiveness.

Effectuation Theory

The effectuation theory is a recognizable theory in the entrepreneurial settings which talks about the decision-making under the conditions of uncertainty (Patnaik & Hashir, 2024). This approach is totally different from the traditional causation logic. The theory is built on stakeholder co-creation, affordable loss, and leveraging the means available while not pursuing the predetermined goals based on the acquired resources (Nielsen & Lassen, 2011). The effectuation ideas have a common ground with the software development practices that are present in the Open Source Software (OSS) development since the same approach is taken where the outcome is the by-product of a collaborative work between people with different positions, motivations, capabilities, and the types and amounts of resources they own.

The effective rationale of taking the resources and building through dependencies is the same as how organizations interact with OSS communities. instead of defining all the requirements for the software and bringing in the resources for development, organizations that are driven by the effectual approach take advantage of the code that is already existing in the community, put in their share of development part by depending on the capabilities that are available and in the end, they make the solutions through a connected and repetitive partnership. This match suggests that the principles of effectuation can suggest the key points of good OSS tactics. Still, as effectuation illustrates the strategic direction and decision-making processes, it does not give the quantified indicators for the innovation outcomes such as the speed of development and the quality of the products (Dugbartey & Kehinde, 2025). The proposed OSSD scale comes to the rescue by concretizing the outcome aspects which basically mirror the effectual success in open-source settings.

New Product Development Models

The traditional New Product Development (NPD) models, such as Cooper's Stage-Gate framework, looks innovation as a sequential and centrally controlled process progressing through clearly defined stages from idea generation to commercialization part (Atuahene-Gima & Wei, 2010). These models have been useful when it comes to proprietary development contexts by balancing managerial control with process acceptance and quality assurance. In contrast, OSSD works through decentralized, parallel, and iterative development cycles involving distributed contributors from all around the world. Development activities often occur parallelly across project components, decision-making authority resides within community structures, and quality assurance is embedded continuously through peer review and collective validation rather than formal, internally controlled testing stages (Y. Li et al., 2025). As a result, conventional NPD measurement approaches are limited in capturing OSSD performance. Drawing from NPD theory, this study hypothesises OSSD as a distinct but related innovation process and adapts core innovation performance dimensions to the open-source context for any kind of product development in the software world. Product Speed reflects the ability of OSS projects to rapidly iterate and release outputs without rigid stage-based constraints, while Product Quality captures robustness and reliability ensured through community-driven quality mechanisms. This theoretical positioning preserves alignment with established innovation literature while providing a contextually appropriate foundation for measuring OSSD performance, particularly within the Indian industrial ecosystem.

3. NEED FOR A CONTEXT-SPECIFIC OSSD SCALE

Emerging economies, including India, have seen a rise in the use of open-source software. However, there is not much empirically supported impact assessment with the help of strong psychometrically sound instruments in the field of open-source software (OSS). The already existing innovation scales are either too broad, and it results in them not being able to recognize the specifics of the OSS sector or they are completely based on the conventional proprietary software systems thinking that this kind of structure is inapplicable in the case of open-source development. On the one hand, the use of innovation scales is very helpful for measuring the degree of innovativeness in general terms; on the other hand, they can never pinpoint the particular things which is necessary for the engagement with OSS. Things such as community coordination, distributed quality assurance, and rapid iteration within collaborative frameworks may differ from firm to firm but are still available on the market. Measurement tools must be developed urgently that would enable organizations, which are driven by OSS, to deal with the challenge of speed and quality together, specifically in the sectors where being quick and flexible make one a leader.

4. METHODOLOGY

This study used a two-phase quantitative design for the psychometric validation of a context-specific OSSD scale for the Indian industry. The study included the recognized protocol for the kind of development of new psychometric scales (Ali, 2024). The research applied both exploratory and confirmatory procedures for the factorial validity, then followed by studying reliability and external validity using different samples (Dalawi et al., 2025). The main aim of Study 1 was to factor structure through EFA and CFA. The second study focused on the areas of reliability, convergence, discrimination, and predicting criteria. The construct of the studies consisted of measures like Product Development Time (PDT), Customer Satisfaction (CS), and Cyberbullying Attitude Scale (CBAS) which were determined for the purposes of comparing dissimilarity (Syamil et al., 2004). The process of validation was strict and at the same time did not contain the typical issues of methodological restrictions in the simultaneous development of scales with the help of different constructs in a single study.

Study 1: Participants

The first study was aimed at examining and confirming the basic factor structure underlying the OSSD scale. The participants for this study were taken from Indian organizations from a variety of sectors including Information Technology (IT) & Business Process Management (BPM), Science and Technology, E-Commerce, Banking, and Education and Training. The sectors were selected with the help of available appearances of the actors with respect to the software development area and the OSS utilization possibilities. The research was based on the responses received through the online surveys, telephone interviews, and in-person discussions and dialogues at the conferences and industry meetings a total of 480 responses were finalised. This size of the sample is considered quite large and therefore gives the factor analytic procedures a good advantage of detecting and extracting the factor structures and by doing so also the very exact estimation of the model parameters. The people who filled the forms are given in *Table 1* along with information regarding their background. There was the purposive random sampling, a kind of sampling, for the selection of the participants as a hybrid approach was applied by mixing a set of randomly selected samples with criteria-based ones so that a balance between relevance and representativeness could be maintained (Bansal et al., 2025). The purposive part took a deliberate process to reach organizations that were already involved in OSS-related activities and data was collected from them through a pre-screening questionnaire which confirmed that they were into the development, contribution, or utilization of open-source technology. This criterion established that the chosen sample should have the necessary characteristics for scale validation and at the same time, the items present in the OSSD should possess the characteristics that could bring forward the right one. This blending of two functions is the basis for the suggested rigorous method that also ensures relevancy of the criterion for the psychometrical validation study. The complete sample, in turn, received a splitting where two equal groups of 240 subjects each were formed to ensure that the factor analysis process was very strong and to avoid any future exploitation of the specific sample's characteristics. The first half was the subject of the Exploratory Factor Analysis while the latter half was saved for Confirmatory Factor Analysis. This method of using split-sample is seen as the best way as it allows the factor structures to be cross-validated in one study and at the same time maintains samples totally independent. Respondents in the first subsample had varied demographic characteristics, and they represented a wide range of sectors and types of organizations. The IT and BPM sector was the most dominant as it outnumbered the rest with 55.8%, followed by Science and Technology (25%), E-Commerce (13.3%), Banking (3.3%), and Education and Training (2.5%). The mentioned distribution of sectors is a rendering of the preponderance of OSS activities in industries that are technology-intensive, still leaving out the upcoming OSS application domain. Of all the organizations that participated in the survey, 90.8% were Private Limited, with the others being universities or research institutions (4.2%), Public Limited (2.1%), and Limited Liability Partnerships (2.9%). From the business classification point of view, 75% startups were those that had been recognized by the government and were registered with the DPIIT (startup India), while 12.5% each represented MSMEs and unlisted entities. Companies that had been in operation for under five years were the most common, with 39.6% being one-year-olds and 50% between one and five years. The expertise in OSS adoption was largely recent: as high as 68.8% had been developing OSS for less than five years, 27.9% of that number had surpassed that period (i.e., 6-10 years), and only 3.3% had been developing OSS for longer than ten years.

Instruments

A structured questionnaire was designed for the purpose of gauging the attitudes and practices connected with OSS development and such a questionnaire was constructed by applying the psychometric principles and scale formatting that have been already validated and used. The research, conducted this way, consisted of three parts. In the first part, which was a more general one, participants were asked to state their age, gender and nationality. For the second (OSS practices) section, the higher authority of the firms were required to indicate the development context of their daily work practices. The third section, on the other hand, required all the participants to tell the frequency of their OSS developments in the last year, and if the developments were denied, they should explain the reasons for that. In the second section, the proposed OSSD scale was presented, with a theoretical foundation in the literature of innovation performance and adaptability for the contexts of open-source development. Two hypothesized factors, namely, Product Speed and Product Quality, included ten survey items complying with the factor model of the scale to be formed. Through the item development process, a series of steps with better theories and methodologies ensured greater practical validity. The Product Speed group's items were mostly from a scale that is known for being the first in speed in the market, but slightly changed to indicate the rapidity of OSS dynamics such as the rate of detecting and fixing bugs.

Ten statements were developed to represent two hypothesized factors: Product Speed and Product Quality. These items were adapted from the innovation speed scale by Chen and Hambrick (1995) and the innovation quality scale by (Lahiri, 2010). Respondents were asked to rate each statement using a seven-point Likert scale, where 1 represented “strongly disagree” and 7 represented “strongly agree.” Example items included: “Our organisation is quick in resolving issues and bugs in open-source projects compared to key competitors,” and “Our organisation excels at launching high-quality open-source products compared to key competitors.” The third section of the instrument included additional constructs to be used in *Study 2* for validity testing; however, these were not included in the analysis of *Study 1*.

Table 1 Demographic information

Table 1 Demographic information

Variables	Category	Study 1 – Subsample 1	Study 1 – Subsample 2	Study 2
Industry / Sector	IT & BPM	134	142	168
	Science and Technology	60	48	98
	E-Commerce	32	20	22
	Banking	8	10	2
	Education and Training	6	20	10
Incorporation Category	Private Limited	218	215	249
	University / College / Section 8 / Research Institute	10	9	7
	Public Limited	5	4	9
	LLP	7	12	35
Organization Category	Startup (Recognized by DPIIT)	180	198	235
	MSME (Registered on MSME Portal)	30	20	12
	Unlisted	30	22	53
Organization Existence	Less than 1 Year	95	143	170
	1–5 Years	120	78	98
	6–10 Years	20	15	27
	11–15 Years	5	4	5
Experience in OSS Development	1–5 Years	165	208	267
	6–10 Years	67	22	18
	11–15 Years	8	10	15

Source: Author representation from data filled by respondents

Procedure

The participants were informed about the study's aim with simple instructions at the start of the survey, which were given either face-to-face or digitally depending on the data collection mode. The introduction involved the statement of the investigation area, which is also the main feature of the open-source software development, without creating any artificial guesses that might alter the participants' answers. The volunteers were allowed to participate, and the consent forms were signed by all the respondents who finished taking the questionnaires. The confidentiality and anonymity of the responses was guaranteed, and the handling procedures were described to avoid the concerns of the organizational sensitivity.

The questionnaire was given in English without any translation, taking into account that English is the primary language for most of the businesses. This methodology became prevalent inside the section of technology followers who are accustomed to English-language materials such as documentation, community chat or forum, code etc. All the responses obtained were thoroughly checked for being valid and their uniformity, if their details were of a partial or stereo type nature they were left out of the analysis. After the responses were sifted through and the dataset was divided into two - giving equal portions for Subsample 1 (EFA) and Subsample 2 (CFA) by means of SPSS randomly selecting of samples. The even numbered replies were picked for Subsample 1 and Odd for Subsample 2, so that the random assignment is ensured within the two samples.

Data Analysis

Data analysis involved IBM SPSS v29 for Exploratory Factor Analysis and AMOS for Confirmatory Factor Analysis. The dataset was scanned for suitability prior to EFA using recognized methods. The Kaiser-Meyer-Olkin (KMO) measure showed a good value of 0.914 implying a good sample for factor analysis which exceeds the threshold of 0.70, indicating that the sample was adequate for factor analysis. Bartlett’s test was also significant at $p < 0.05$, confirming that the data were factorable. Exploratory Factor Analysis was conducted using Principal Axis Factoring with Promax (oblique) rotation to allow for potential correlation between factors. The analysis produced a two-factor solution that accounted for 86.85% of the total variance in the dataset. Each of the ten items loaded strongly onto one of the two factors, with all factor loadings exceeding 0.90. Communalities (h^2 values) were also high, generally above 0.85, indicating that a substantial portion of variance in each item was explained by the factors. The initial term was identified as Product Speed, with its components involving fast product development, bug fixes, feature releases, and also frequent iterations. The following term, Product Quality, was an outcome of items focusing on such things as software quality, efficiency, the establishment of contribution criteria, and organizational support for the open-source software quality. This bi-dimensional solution was in congruence with the predicted structure that was based on theoretical analysis and item-generating procedures. To gain the support of two-factor mode extracted from Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis was applied to Subsample 2 with the help of AMOS, the software for the analysis of structural equation models. CFA was able to test through this method if the two-factor theory-based structure is able to duplicate the pattern of the observed covariance matrix in a completely separated sample. The model was able to show a proper performance through the different measures of fit; Root Mean Square Error of Approximation (RMSEA) = 0.012, much lower than the 0.06 threshold for excellent fit; Standardized Root Mean Square Residual (SRMR) = 0.017, which is below 0.08; Goodness-of-Fit Index (GFI) = 0.975; Comparative Fit Index (CFI) = 0.982; and Tucker-Lewis Index (TLI) = 0.943. The chi-square value was 58.452 with 34 degrees of freedom ($p = 0.028$). The chi-square significance, although it is a statistical test, was still expected in the case of a satisfying sample size; however, the indicators of the model fit did not go below the required thresholds even once.

In *Study 1*, it was cross validated that the OSSD scale had a stable factorial validity. Product Quality and Product Speed were the two-factor structure that Product Speed and Product Quality were identified as the two latent factors. The factor structure was empirically tested with a confirmatory factor analysis, which revealed that the data were well-represented by the model.

Study 2: *Participants*

The survey in Study 2 verified whether the OSSD scale with totally separate ten-factor, two items could be reliably and validly used or not as initiated in Study 1. The new set of 300 Indian organizations and their participation in the research were such that they were not overlapping with the Study 1 samples that were used for the validity test thus preventing any influence from the sample characteristic that might have been present in Study 1. The sample size chosen for this purpose was a consequence of the power analysis and was aimed to be sufficient for the purpose of applying the range of statistical techniques mentioned in the test without constituting the samples that have been used to develop the scale. As in the first survey, the participants came from sectors such as IT and BPM, Science and Technology, E-Commerce, Banking, and Education and Training. The sample was taken by purposive random sampling, which aimed at companies that were actively working in the field of software development and in particular; which were using free and open-source technologies. The purposive sampling method was justified as it ensured the companies with the organizational relevance to OSS practices through the open-source engagement confirmed by answers to the screening questions. The random selection from the designated population improved the transferability of the results which was the case despite the still being the sample separated from the Study 1 participant's sample.

Table 2. Exploratory factor analysis results: factor loadings, communalities, and eigenvalues for the OSSD scale

No.	Statements	Loadings	h²	Eigenvalues
Product Speed				**4.352**
1	Our organization is quick in contributing novel ideas to open-source projects compared to key competitors.	0.929*	0.889	
2	Our organization is quick in launching new open-source products compared to key competitors.	0.927*	0.884	
3	Our organization is quick in developing new features or updates for open-source software compared to key competitors.	0.940*	0.863	
4	Our organization is quick in adopting and implementing new processes for open-source development compared to key competitors.	0.943*	0.859	
5	Our organization is quick in resolving issues and bugs in open-source projects compared to key competitors.	0.926*	0.857	
Product Quality				**4.319**
1	Our organization excels at contributing innovative ideas to open-source projects compared to key competitors.	0.929*	0.874	
2	Our organization excels at launching high-quality open-source products compared to key competitors.	0.933*	0.870	
3	Our organization excels at developing robust and feature-rich open-source software compared to key competitors.	0.928*	0.863	
4	Our organization excels at improving processes in open-source software development compared to key competitors.	0.935*	0.861	
5	Our organization excels at enhancing management practices for open-source software projects compared to key competitors.	0.922*	0.850	

Total number of items: 10, Total Eigenvalue: 8.685 Explained Variance: 86.85%,

Source: Primary Data, Note: Satisfactory Factor Loadings ≥ 0.50; h² = Communalities

Demographic trends closely replicated those of Study 1, providing essentially the same population representation and facilitating a meaningful comparison across the two investigations. The industry attribute of IT and BPM being the leading sector was the same (56%), while Science and Technology gained the second position accounting for 32.7%, and E-Commerce and Education and Training were double-digit each with 7.3% and 3.3% respectively. As for the forms of organization the companies took, 83% were private limited entities, the rest being shared by LLP and public firms plus educational and government institutions. As for the legal status, 78.3% were considered as government-recognized startup companies, 17.7% were not listed, and 4% were MSMEs. The OSS practitioner experience distribution states that 89% belonged to the category of having one to five years of background, 6% having six to ten years, and lastly, 5% having more than ten years of acquaintance with open-source software. This consistency in the demographic variables shows that Study 1 and Study 2 have similar respondent samples from the OSS-leaning Indian company population.

Instruments

Utilizing the structured questionnaire from the first investigation, the OSSD scale, which consisted of ten items and has undergone validation, was completed by the participants, measuring Product Speed and Product Quality with the help of the seven-point Likert format. Moreover, the research used three different instruments to evaluate relational construct validities by establishing relationships with constructs that were either close to or distant from the theoretical premise.

Customer satisfaction: was calculated via an integrated scale that was tested in both service and software areas. This scale was the one by Terpstra et al. (2013) and it includes the three dimensions of perceptual quality, responsiveness, and general satisfaction with the company's outputs. For the accuracy of the data about the validity of the criterion, the CS, which was a part of the study and was very close to the constructed theory, i.e. the learning organization, was used to examine the criterion validity. It was anticipated that organizations that promote high levels of customer satisfaction by being more innovative than the competition would register greater customer satisfaction levels.

Product Development Time: This factor is measured with some of the basic industry measures like lead time (the time span between the request and delivery), cycle time (the duration of each stage), and time-to-market (the period from concept to launch) (Attarmoghaddam et al., 2022). Even though PDT is not a psychometric measurement, it is commonly used in actual studies to compare the productivity of the development process. Moreover, PDT was the key predictor being taken in the evaluation of predictive validity, and it was done by determining whether the dimension of the OSSD scale was able to forecast the change in development performance which was also statistically significant.

Cyberbullying Attitude Scale (CBAS): It was first introduced by Bansal et al. (2022) which is a measurement with two factors that evaluate the person's general attitudes towards cyberbullying behaviors and cyberbullying as a whole. The reason we choose CBAS as a construct that is not related to the OSSD scale is that we wanted to demonstrate the validity of the scale by showing that there is no dependence of the OSSD scale on unrelated psychological domains. Possible implications of this study include the discovery of construct specificity of the proposed innovation via CBAS-OSSD non-significant links.

Procedure

All the survey invites were sent by email and the in person meetings, method was also made use of for the same data collection process as used in Study 1. With the new instructions, the survey reemphasized the scientific objective of the study but did not go into the specifics of the research. Just like Study 1, the informed consent was an essential part and the anonymity of the participants' answers was guaranteed. The language used for the final questionnaire was English given its wide circulation in Indian tech and OSS community communication spheres. Before any statistical analysis was done, every respondent's responses were checked for their completeness and also their consistency, and any responses that were either suspicious or incomplete were not considered in the study.

Data Analysis

The reliability, convergent validity, discriminant validity, and predictive validity of the OSSD scale were assessed through the different methods in this phase. Two of the most commonly used methods for quantifying scale reliability, Cronbach's alpha, and Composite Reliability (CR), were used Bhandari et al. (2024) but considered as internal consistency just in the former. One of the two constituent parts, the Product Speed subscale, had Cronbach's alpha 0.825 and CR 0.89, and the other part, the Product Quality subscale, had Cronbach's alpha 0.865 and CR 0.85. Each subscale showed very good internal reliability, the high level and, therefore, adequate fairly straight-forward still measurement of the to be completed, depending on the constructs' nature.

Table 3. Correlation matrix between OSSD dimensions and external variables

Scales	OSSD	Speed	Quality	CS	PDT	CBAS
OSSD	1					
Speed	0.870*	1				
Quality	0.854*	0.862*	1			
CS	0.751*	0.678*	0.670*	1		
PDT	0.780*	0.760*	0.693*	0.681*	1	
CBAS	0.011	0.032	0.108	0.048	0.127	1

Source: Primary data. OSSD (Open source software development), CS (Customer Satisfaction), PDT (Product Development Time), CBAS (Cyberbullying Attitude Scale)
**Significant at p < 0 .05.*

When trying to prove Convergent validity, the Average Variance Extracted (AVE) technique was utilized, which is a way of calculating the proportion of variance in indicators that is due to the latent construct. The AVE figures for Product Speed and Product Quality were 0.62 and 0.55 respectively, both of which were above the 0.50 threshold deemed adequate. Thus, these numbers show that most of the variance in scale items are a reflection of the underlying constructs rather than the measurement error, thus giving evidence in favor of the convergent validity of the variables.The discriminant validity was checked by means of Fornell and Larcker (1981) criteria, with the basic rule being that the square root of AVE for each factor should exceed its correlations with other latent variables. Findings supported this rule, displaying that both factors were much more related to their own indicators than to other constructs. In addition, the correlations between the OSSD scale dimensions and CBAS were not statistically significant, thus furnishing further evidence for the discriminant validity of the Construct. The fact that attitudes toward cyberbullying were not correlated with the constructs of innovation or any other constructs confirms that the OSSD scale captures not only the general variance of responsiveness but also the specific innovation-related variance.

Pearson correlation analysis was used to assess the criterion validity by relating OSSD dimensions to CS and PDT. It was discovered that there is a strong positive correlation that is statistically significant. Product Speed and Quality were each positively associated with higher customer satisfaction and shorter development times. Hence, Product Speed and Product Quality had shown strong positive correlations with the other two (CS and PDT).The evaluation of predictive validity was carried out through multiple regression analysis with-performance development time (PDT) dependent variable and product quality and speed independent predictors (OSSD). The beta coefficient was standardized to 0.449 for Product Speed, pointing out that each point of standard deviation in Product Speed leads to a standard deviation decrease in development time by 0.449. Product Quality got the beta coefficient of 0.467 which is also a comparable magnitude of impact. They both hit the p less than 0.05 significance level.

Table 4 Reliability and convergent validity of constructs

Construct	No. of Items	Cronbach's Alpha (α)	Composite Reliability (CR)	Average Variance Extracted (AVE)
Product Speed	5	0.940	0.948	0.822
Product Quality	5	0.936	0.945	0.817
OSSD	10	0.926	0.852	0.743

Source: Primary Data, Threshold Criteria: $\alpha \geq 0.70$, $CR \geq 0.70$, $AVE \geq 0.50$

The overall model has been able to justify the 51.4% PDT variance (R2 = 0.514) which means the two OSSD dimensions are responsible for more than half the variation in time taken for the development process. The model's F-statistic was 28.031 ($p < 0.05$) showing the statistical significance of the result of the overall prediction. All these results are a big deal because of the impressive predictive validity that the OSSD scale possesses being a organizational capabilities with practical development projects outcomes. One interesting implication is that for organizations achieving very high scores on product speed and quality, there is a great deal of reduction in development time experienced, and this leads to the scale being a very relevant tool for innovation performance the assessment with practical implications.

Table 5 Regression analysis predicting product development time (PDT)

		Unstandardized coefficient		Standardized coefficient		
Model	Variable	B	Std. error	Beta	t	Sig.
1	Constants	1.340	0.601		8.111	0.05*
	Speed	0.431	0.644	0.449	11.003	0.05*
	Quality	0.834	0.672	0.467	9.233	0.05*

**Significant at p < 0 .05.*

				Change statistics		ANOVA	
Model	R	R square	Adjusted R square	F changes	Sig. F changes	F	Sign.
1	0.717	0.514	0.479	28.031	0.000*	28.031	0.05*

**Significant at p < 0 .05.*

Figure 1. Confirmatory factor analysis measurement model of OSSD

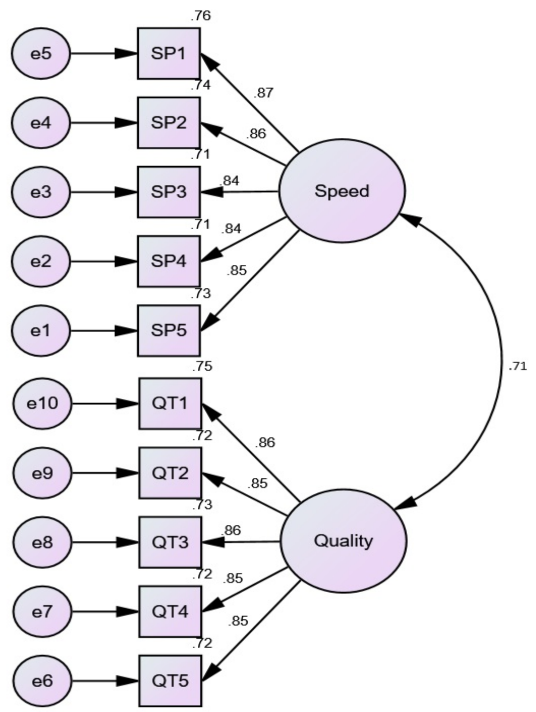

Figure 1:Source: Primary Data, Standardized CFA measurement model showing Product Speed and Product Quality with their observed indicators and latent correlation using SPSS AMOS

5. DISCUSSION

The main aim of this paper was to develop and validate a psychometric scale for measuring the open-source software development performance in the perspective of the Indian industry. This had to be carried out in two stages that involved factor analysis and external validation. This research ended up creating a parsimonious two-factor, 10-item scale capturing major dimensions of product speed and product quality by combining the two. This indicates the manner in which organizations structure their innovation within open-source contexts. It addresses a notable gap in the measure of open-source performance, particularly in the Indian ecosystem.

The study 1 results establish robustness in the sheer factorial validity of the scale. The exploration and confirmation of factors have also determined two independent and namesake constructs: Product Speed and Product Quality. Product Speed adds to Product Innovativeness in speeding up new launches and outputs, hence proving that going to market earlier is also a source of competitive advantage (Wu et al., 2019). The Product Quality dimension captures the reliability, extendibility and control effectiveness of the OSS initiative aligning with previous findings that quality as a driver for long term adoption and performance (Chaithanapat et al., 2022). It broadens the spectre from the established perspectives of innovation management and the product development by joining the context appertaining to open source.

Now study 2 has further confirmed the reliability and predictive value of the OSSD scale. Psychometric integrity of both dimensions was supported by high internal reliability values, while the scale demonstrated evidence of convergent and discriminant validity by having the correct construct measured by OSSD and non-related constructs accordingly. Verification and validation of both instruments were attained, as well as significant correlations with CS and PDT, hence reinforcing the simultaneous validity of OSSD.

Regression analysis showed that both Product Speed and also Product Quality significantly predicted PDT, accounting for a substantial proportion of variance. From this, practical developmental effectiveness results in increased performance of the technical aspect of the system, besides the fact that new OSSD practices also appear in less-keeping secret that echoes the operations of many startup ecosystems across India.

At the theoretical level, the work integrates innovation frameworks such as New Product Development, Diffusion of Innovation, and Effectuation Theory into a contextually validated instrument development for OSS. Overall, results revealed the relevance of deploying a balance of speed and quality in open-source context-as indicated above-that distinguishes such organizations in India as better positioned to superior innovation outcomes amidst a constantly and heavily competitive industrial environment.

6. IMPLICATIONS

Theoretical Implications

The validated OSSD scale enhances innovation management theory by establishing a systematic measurement framework for the investigation of OSSD in organizational settings. Conventional innovation theories, such as Diffusion of Innovation (Rogers, 2003) and Effectuation Theory (Sarasvathy, 2022), presents general guidance on innovation processes but do not have specific metrics for gauging performance in the context of open source software. This research fills this gap in theory by presenting a strong and psychometrically valid questionnaire that defines OSSD performance across the two dimensions of Product Speed and Product Quality.

The distinction between Product Speed and Product Quality is a reaffirmation of modern innovation environments duality by needing both quick changes and a high level of output. These are the two main abilities that companies dealing with Open Source Software (OSS) have to possess to be quick and long-lasting. The validation of these two concepts goes far beyond-the-border innovation theory where the different operation modes in the software development process are closely coupled with the quality management system which is more of a shared concern in that environment.

This study extends the feasibility of the NPD model to open-source contexts. Despite the tendency of the NPD frameworks to mainly focus on stage-gate processes in closed settings (Datar et al., 1997), this research shows with practical examples that innovation in the OSS community can be measured by the incorporation of fastness and quality as the main criteria. The paper promotes the advancement of theories to enable the inclusion of hybrid or decentralized development models that are becoming typical in technological sectors as well as economies that are on the rise. This scale also gives alternative uses such as confirming the similar measures in other cultures, tracking the OSS innovation capability over time and finding similarities and differences between the various development models points to the future directions of the NPD research.

Practical Implications

The OSSD Scale has not only been tested and proven to be valid but has also got a lot of demand when it comes to utility in the changing face of technology, more especially with the open-source movement. It is now being used by many organizations not to only measure their innovation and software quality capacities but also to improve them. The scale will be very helpful in removing difficulties that development groups face regarding new talents and resources. Its regular users will also receive the advantage of a managerial perspective in strategic planning and resource allocation. The application of this scale in already founded companies will give the management a chance to take measures that will help the company to become even more competitive in the tough market.

Policymakers and institutions that have been supporting the Indian startup ecosystem can use this scale as a tool of measuring performance, including the initiatives under the Start-up India and Digital India programmes. It can be used as systematic in government-funded innovation schemes evaluation against the predetermined criteria and thus support the policy refinement based on the evidence. Venture capitalists and investors are able to see the OSS-related capabilities in technology-driven startups through this scale. In the narrower sense they are able to complement their traditional due diligence which is mainly financial position, team strength, and market opportunity oriented.

7. LIMITATIONS AND FUTURE DIRECTIONS

This study imparts a significant amount of knowledge on innovation management through OSSD scale construction and validation, but at the same time, several limitations should not be overlooked. One of the major drawbacks is the geographic limitation of the study to Indian organizations, especially those in the most demanding startup sectors. The conditions of the place, such as culture, laws, and economy, which are unique to India, can be the determinants of local practices of OSSD and their implementation that can make it difficult to generalize to other situations. The study will be more useful if future studies are conducted on large occasions, through an examination of various countries or regions to determine the extent of applicability.

The second limitation is the cross-sectional design that does not allow for the observation of the changes in the progress of the OSSD capabilities over time. Innovation capabilities are sure to change over time as organizations grow, enlarge their networks of contributors, or implement new technologies. The longitudinal/optical studies would have the ability to examine the temporal stability and the developmental pathways of the OSS capabilities across the different growth stages of organizations.

Next, tech-reliant domains and industries in general are more exposed to the use of OSS tools. The rest of the industries that are involved could see and treat the OSS principles in a different way which would result in the sector-based modifications or even the mitigating effects' scrutiny. Next, besides PDT and CS, the rest of the company-internal factors such as the culture, management, and technical support could contribute to the variation of the OSSD's productivity. That is why the upcoming models should include such various non-technical issues in order to have a total grasp on the causes of the OSS performance.

The contextual understanding is not complete without the presence of qualitative insights. Additional nuances of how organizations deal with speed-quality trade-offs in OSSD environments can be exposed with in-depth interviews or case studies. It should be the future research to spread the scope further by cross-cultural validation, longitudinal tracking, sectoral analysis, and qualitative exploration to strengthen the robustness of the OSSD scale and develop more globally relevant theory of open-source innovation.

8. CONCLUSION

This research is very useful to the field of innovation management and product development in terms of software by providing and testing a particular scale for assessing OSSD practices within the Indian industries. The two-stage methodological process has been conducted employing a combination of EFA and CFA and led to the creation of a stable second-order structure consisting of two first-order dimensions which are Product Speed and Product Quality and are made up of ten measurement items in total. These dimensions capture the essential dual imperatives of responsiveness and reliability that characterize effective innovation in open-source ecosystems.

The empirical findings confirm that the OSSD scale performs strong internal consistency, along with convergent and discriminant validity which is satisfactory in nature. The results demonstrate that the construct possesses adequate predictive validity, as evidenced by its significant associations with relevant performance-oriented outcomes. Importantly, the scale was empirically distinguishable from conceptually unrelated constructs, reinforcing its theoretical clarity and measurement precision.

From a theoretical point of view, this study extends existing innovation-related frameworks into the open-source domain by offering a validated measurement instrument where such tools have been largely absent. If we talk about the prior theories such as NPD, Diffusion of Innovation, and effectuation perspectives acknowledge speed and quality as critical innovation outcomes, they have produced limited direction on their systematic measurement in distributed and collaborative OSS contexts. By working on the OSSD through empirically grounded dimensions, this research helps align established innovation theories with contemporary open-source development practices.

Practically, the validated OSSD scale offers a valuable indicative tool for institutions, organisations, policymakers, startups, and incubators seeking to assess and support their open-source innovation capabilities. In competitive environments where the rapid development must be stabilised with high product quality, and the speed also the ability to reliably measure these dimensions provides meaningful strategic insight, mostly for Indian organisations working under resource constraints and market volatility.

Finally, this study emphasises on the importance of contextualization in measurement development. Although existing research on OSS has primarily focused on Western settings, limited attention has been given to the cultural, institutional, and developmental characteristics of emerging economies. By validating an OSSD scale tailored to the Indian context, this research lays a strong foundation for future empirical studies and contributes to a more nuanced understanding of open-source innovation in India.

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