

A scientific view and analysis of theatre art yakshagana

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ABSTRACT

Many of the Indian performing arts have deep scientific/engineering aspects involved in them without being recognised or studied. Yakshagana is one of such arts being performed in coastal districts of Karnataka and has a history of more than 500 years. Yakshagana is a team, multidisciplinary art involving classical music, percussions, dance, dialogue, comedy, costumes, and scholarly discussions. This article discusses the components/parameters of the Yakshagana art form from a scientific and engineering perspective, and we have attempted to formulate mathematical equations for a better understanding of the art execution, artist's capacity and overall performance. Empirical mathematical relations are formulated to estimate the performance index to grade the quality of the overall performance of the day. As art is an "all-in-one" form of art performance, it is represented using a Venn diagram. Four main components of Yakshagana and the importance of the coordination between them for successful, cohesive and high-quality performance are analysed by incorporating scientific and engineering approaches. We hope that the present study will open up further scientific research on long-duration performing Indian traditional art forms.



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1. Introduction

India is the origin and home for a variety of forms of music, dance, drama and a variety of performing mono and group arts. No country in the world has a greater variety of forms in music, musical instruments, costumes, make-up, dance, and theatre arts than India has. One of the typical theatre art forms, Yakshagana, originated in the coastal Western Ghats of Karnataka, generally or may be wrongly described as folk but possessing a strong and unique classical connection, is the group performing art. *Yakshagana* literally means the *yaksha* (nature spirits) [1]–[4] are the people (*gana*) who bring to life the characters and stories drawn from Indian epics Ramayana, Mahabharata, Bhagavata and Purana through the rhythmic combinations of singing, accompanying instruments (middle, change), dance, acting, improvisation, expressions, dialogues, scholarly discussions, comedy with typical costumes and make-ups. Yakshagana is the scholastic name used for the last 200 years though the earliest Yakshagana manuscript in Karnataka goes back to A.D. 1651, the art form formerly known as *aaṭa*, *bayalaata*, *harake aaṭa*, and *dashaavataara* [1], [5]–[11]. Although the name signifies the music of celestial beings, Yakshagana is an amalgam of the sky with the earth. In Karnataka's coastal and Western Ghats regions, art is closely associated (mingled) with culture, social life, beautiful greenery and the ecology of Western Ghats.

The Western Ghats are known to be one of the world's biodiversity hotspots [11]; the region is also known for ecological, cultural and artistic diversity [12]. The art Yakshagana goes well with the Western Ghats ecosystem as both have diversity: Western Ghats are known for global biodiversity, whereas Yakshagana (originated in Western Ghats) is known for artistic diversity. Many research works are carried out on biodiversity, ecology, rivers, forests, habitats, and life, in western ghats [11]–

[13]; however, there is a need to scientifically study the art diversity, ecosystem and culture of the region associated with the Yakshagana art. There is both mystery and robustness about this art form in which singing and drums beating merge with costumes, dancing, expressions, actions and words with gestural interpretation, followed by dialogues and discussions while keeping the *prasanga* (story) moving forward. The most striking attraction of this dynamic art is that the performers are clad with glittering costumes and make-ups of appealing colours, tilaka, moustaches, aesthetics and contours to suit the characters of the day's *prasanga*. Singing is always accompanied by percussion instruments such as *maddale* and *chande*, *tala* (cymbals), and *shruti* (harmonium or electronic tuning box currently).

Yakshagana in coastal Karnataka has two traditions (styles): *badagutittu* and *tenkutittu*. Both traditions follow the *himmela* (*bhaagavata*, *tala*, *maddale*, *chande*, harmonium for *shruti*) group and the *mummela* (stage character performers) team, composed of performing artists. The *himmela* in both styles is more cohesive to the entire production. The rhythms of the *chande* and *maddale* coupled with the *chakrataala* or *jaagate* of the *bhaagavatha* create an excellent symphonic sound and performing energy. The *mummela* (dance, expression and dialogue) team dressed in colourful costumes (defined characters) dance (*kunitas*), create emotional expressions, followed by dialogues/discussions and keep the story moving. *Himmela*, mainly *bhaagavata*, who narrates the story by singing, is also responsible for conducting the entire performance and keeping time. Though there are few differences and many similarities between the two traditions, the two styles of Yakshagana can be performed together or even simultaneously. However, changing trends over the years in the performance of Yakshagana is also being observed and studied.

Badagutittu: The *Badagutittu* style is prevalent in Uttara Kannada District and the northern parts of Udupi Dist. from Kundapura to Byndoor. The *Badagutittu* form of Yakshagana gives more emphasis on facial expressions, dances appropriate for the character depicted in the episode well supported with *bhaagavathike* (singing and *tala*), different *kunitas* (steps and combination of steps), expressions followed by profound *maatugarike* (dialogues) and discussions. It makes use of *maddale* (*mridanga*) and typical *Karnataka chande*. The singing here appears to have Hindustani music influence. The dance form in *badagutittu* strikes the attention of the audience with varieties of *kunitas* (dance improvisation) and deep expression of all contrasting emotions (*nava rasas*) based on *pada* (song), and *mandari* (spinning on the knee) *kunita* and many more [14], [15].

Tenkutittu: The *Tenkutittu* style is prevalent in Dakshina Kannada, Kasaragod Districts, western parts of Coorg (*Sampaje*), and a few areas of the Udupi district. The influence of Carnatic music is apparent in *tenkutittu*, as evidenced by the type of *maddale* and *chande* used and in *bhaagavathike*. Yakshagana is influenced more by folk art blended with typical classical music and dance aspects of its own. The dance form in *tenkutittu* strikes the attention of the audience with *dhiginas* (jumping spins in the air) or '*Guttu*' *kunita*, its extravagant *rakshasas* (demons) and many more, followed by dialogues and scholarly discussions. In *tenkutittu*, three iconic sets of colours are used: the *Raajabanna*, the *Kaatbanna*, and the *Sthreebanna*. Typical *badagu* and *tenku tittu* make-ups and costumes for the character Krishna and Rajavesha is shown in Figure 1.



Fig. 1. Typical make-up and costumes for (young) character Krishna; (a) Badagu; (b) Tenku; Rajavesha (King) in (c) Badagu; (d) Tenku

Traditionally this is a whole night (from dusk to dawn), open-air performing art form (from 9 PM-6 AM) almost every day for six months (Nov.-May) of the year. The troupes (*Melas*) travel from place to place each day in the coastal districts, putting the tents during the daytime, performing at night, and again shifting the tent and the troupe to the next planned location in the morning. The performers rest till nightfall and perform in the night, given that the Yakshagana is a night-long performance. For them, night becomes the day and vice versa. Hence, the artists desire greater energy, stamina, patience, and sustainability for long hours and long-life performances to achieve greater heights to become maestros of this art. These expectations are very much similar to that of sports persons. However, athletes normally will hang up their boots at the age of 35-40 years, whereas artists can perform even up to 80 years of age with lifelong learning.

Hence, scientific research needs to understand the nature of performing art, the artist's psychological (psycho-physical) energy for long-duration performance, and sustainability. Many media reports, books, and articles are published on the history, traditions, evolution of the art, top artists' life and other aspects of Yakshagana [1], [4], [6], [8], [9]. Few research works (PhD thesis) are available in literature related to this art form, music, and about late, present great maestros of Yakshagana [16]–[18]. Studies on the voice and vocal health of Yakshagana singers have been reported in the literature [18]–[21]. A case study on the role of Yakshagana in conveying environmental consciousness is also reported [15]. The literature will definitely provide valuable information on this most attractive and dynamic art form. However, true knowledge and insight into this art can be gained only through penetrative experience by watching the real performance. Most of the studies reported in the literature are essentially on the art history, evolution of the art, about artist's life or one of the parameters of the art. However, there is hardly any effort towards scientifically exploring and understanding all parameters/ components and, as a whole, the performance of this theatre art from a scientific perspective. Our study mainly focuses on the scientific and engineering aspects embedded in Yakshagana components and the entire performance. In recent years 'limited-time' (shorter versions) Yakshagana has become more popular because of the busy life schedules of the spectators and other reasons.

In this work, we have attempted to understand different components, aspects and cohesive performance of Yakshagana with scientific insight and approach. We try to formulate mathematical equations that explain the source of psycho-physical/emotional energy, performance quality (quality factor), chemistry, biology between artists and other engineering aspects that are very much involved in this art form for hundreds of years without being scientifically recognised. A survey and interviews were conducted with many senior and younger artists to understand their inspirational source for long-hour performances, longevity and other aspects. Born, brought up in Sirsi in Uttara Kannada District and trained in Yakshagana, the authors have put their scientific research experience into exploring Yakshagana through a fundamental science approach. In this article, we focus mainly on the Badagu and Tenku tittu forms of Yakshagana to evolve into some empirical mathematical models and scientific explanations for the typical parameters and components of the art and the entire performance.

2.. Scientific view and mathematical model formulation

Traditionally, the performances are held in open air or open air-tents; therefore, high-pitch loud singing and similar high-pitch dialogue delivery styles used to be heard over long distances. The *Bhaagavata* (who narrates the story by singing and clapping cymbals) with accompanying percussions is expected to demonstrate contrasting emotions such as devotion, happiness, love, comedy, agony, hate, horror, surprise, bravery, fear, and anger throughout the performance whereas *mummela* artists with defined characters with typical make-ups and costumes perform the same parallelly on *rangasthala* through *yakshagana mudras*, *gattu*, actions, steps with perfect synchronization. These are the backbones of the entire show. In Yakshagana, *Bhagavata* will initiate and drive the performance in a loud and high-pitched voice, accompanying cymbals (*tala*) and rhythmic drum instruments. As the singer renders a poem (*pada*), he keeps increasing/varying his pitch; the *mummela* artist or team dances blended with *kunitas* and expressions followed by dialogue and discussions (philosophical) tuned to the same pitch. In many instances, along the song and story, there is a prolongation (improvisation) of the phrases blended with varieties of *kunitas* (dancing steps) and creative actions to achieve special effects. These depend on the artist's experience, skill, and chemistry between *mummela* and *hemmela*. *Mummela* artists, after prolonged dancing and actions to the respective *pada*

(song), immediately start dialogues and discussions with the co-characters in the same pitch and *shruti*. The voice is quivered or oscillates back and forth from one note to another in a smooth transition with a steady breath flow without any breaks [18]–[21]. Interestingly, the dialogue delivery tuned with a breathing pattern will not show the tiredness of the performer.

The typical features of this art form include prolonged loud, high-pitched singing, similar pitch dialogues/discussions, emotional outbursts during acting, vigorous dance movements and high physical exertion, which result in vocal abuse and physical tiredness. Mummela artists create all these on the stage along with make-up and heavy costumes tightly tied to the body, mainly legs, waist, hands, chest, neck and head. While performing, the artist might modify his breathing pattern or tighten his face and upper body, which might add additional pressure on his entire body and vocal mechanism [18], [20], [21]. Hence to execute the art Yakshagana, artists need to have high and sustainable internal energy. However, there is no scientific study or analysis on the origin of this internal psycho-physical energy and how it stimulates artists to perform longer hours, maintaining all parameters of the art intact throughout the performance and career longevity. At the outset, it appears that there is something to do with emotional-physical energy that keeps the system moving. The breathing regulation in Yakshagana can be compared with Yoga. The main component of Indian Yoga is Pranayama, which involves the practice of breath regulation, an exercise for physical and mental wellness. In Sanskrit, “prana” means life energy and “yama” means control. We observed that for Yakshagana artists, *kunitas* associated with regulated breathing patterns become the practice of pranayama by default. This also may be one of the supporting physical energies for sustained performance. Further, *kunitas*, emotional expressions, mudras, body bending, and stretching the lead to practising different “asanas” of yoga by default.

After interviewing many top artists and the survey conducted with other performers, it is observed that for Yakshagana artists, the typical high-pitched music accompanied by percussions is the main source of psychological (psycho-physical), inspirational energy to perform for a long time. When the artists are ready with make-up and typical costumes, and traditional “Ganapati pooja” is performed in the chowki (make-up tent), they feel energised emotionally to perform. Hence we propose the psycho-physical energy equivalence as the high-decibel combined rhythmic music and percussion that a non-dimensional empirical equation can define.

$$E_p = mc^x + h(x, t) + K \text{ (Yakshagana energy equation)} \quad (1)$$

Where E_p is the psycho-physical energy required for Yakshagana performance, m is *maddale*, c is *chande*, h is *haadugarike* (singing), and K is the *kunita* x is the independent variable depends on the *prasanga* (story), the situations therein and t is the time. Since m , c , h is involved in synchronized, rhythmic sound production, we consider the sounds produced during the performance to be 50-120 dB, stimulating vibrational energy in the body. This synchronised, tuned (*shruti*) loud sound is the main source of stimulating psycho-physical energy and inspiration for contrasting emotional expressions. *Kunitas* can be considered as Yoga (*asanas*), the other energy source for long-duration performance sustainability for the artists of Yakshagana. Many reports show how music therapy can directly impact an individual's physical, emotional, and cognitive functioning [22], [23]. Specifically for Yakshagana, its typical high-pitch music accompanied by percussion are the driving force and the source of the performers' psychological, physical and emotional energy. This is confirmed after interviewing (surveying) many performing artists, thorough observations of many performances, and experiences by the authors. Further, the entire success and quality of Yakshagana performance depend on the coordination between *himmela* (*bhagavata*, percussionists) artists and *mummela* (dancers) artists. Hence, “mutual positive feedback” reinforces the energy between the singing and dancing and the energy that the artists infuse into one another - Himmela to Mummela and vice-versa.

Bhagavata, the musical narrator of the story, gives an emotional voice to all dancing characters through the play based on the situation of the *prasanga* (story) and drives the time-dependent performance to conclude the story. Since this is a group art with many parameters involved, the overall performance (index) of Yakshagana $P(y)$ can be formulated as follows:

$$P(y) = E_p + a(z) + b^n(z) + k \text{ (Yakshagana performance equation)} \quad (2)$$

This is again a non-dimensional empirical expression where stands for main artist (z -experience, skill), b is the co-actors, n is the number of artists for that particular story/day, k is a positive or negative number depending on other factors such as chemistry between *himmela* and *mummela*, day's *prasanga*, performance hall (auditorium or open air), audience support, arrangements at the location and atmosphere. As defined, Yakshagana is an all-in-one performance with music, percussion, dance, dialogue, discussions, comedy, colours, costumes and light. Further, this is the only art form that has two natures (forms) of performance. One is *regular aata* (full-scale open-air performance), and the other form is *Taala-maddale* (*baithak*). *Baithak* is an in-house performance that involves only *bhaagavatike* (singing), percussion, dialogue and scholarly discussions. Dance, costumes, make-up, and stage are not included in this form, but the same *prasangas* (stories) are presented through music and dialogue form. In the conventional '*taala--maddale*,' the artists sit across a place without any costumes and engage in demonstrating their oratory skills based on the episode chosen. It is a Yakshagana minus dance, costumes and stage conventions. Hence Yakshagana (*aata and baithak*) can be called a dual natural performing art. The typical *taala-maddale* set-up and the full-scale (open-air) Yakshagana stage are shown in Figure 2. Thus, it can be compared (empirically) with the theory of light in physics, as light has a dual (wave and particle) nature. Recently third nature is also being presented that involves all other components except the dialogue/discussions still enacting the poetic epics on stage.



Fig. 2. (a) A *baithak* (*Taala-maddale*); (b) Open-air Yakshagana performance (top view)

Yakshagana is an “all-in-one” of performing arts. It has the following art components blended in such a way that one can see most of the Indian performing arts on one platform. The components are; A- Classical, folk music (*raga, swara, shruti, taala, laya*) and percussions; B- Dance (classical, folk), action, emotional expression, mudras; C- Variety of costumes and make-ups, D- Dialogue, scholarly discussion and comedy, E- Stories, theme and take home message, culture and tradition, F- Literature, philosophy, language, G- Improvisation both in music, dancing and scholarly discussions, H- Opportunity for in-situ creations of dance and discussion keeping the rich tradition/story intact. The above components of Yakshagana can be represented using a Venn diagram, which is typically used in mathematics to illustrate possible logical relations between a finite collection of different sets using overlapping closed curves. Here we have represented different (sets) art forms (components A to H) blended in Yakshagana using eight coloured ovals to create the Venn diagram. Each component (set) has other elements (art forms) as members of that set. The central union place of ovals (A-H) is “Yakshagana Rangasthala”, where all art forms are presented, see Figure 3. The other intersecting regions show combinations of other art forms that clearly indicate that yakshagana artists have greater opportunity and flexibility to learn different art forms, blend them into yakshagana form, keep their individuality and tradition and evolve into new forms. The comedy dialogues can be tuned to contemporary social life and politics without violating the yakshagana image, language integrity and the story being performed. This is the only whole night performing art without using a single English word during the dialogue and discussions. Through the Venn diagram, it can be demonstrated that Yashagana is an “all-in-one” art form of teaching life values through entertainment, telling the stories of Indian epics through live characters. Hence we call it a Super-art.

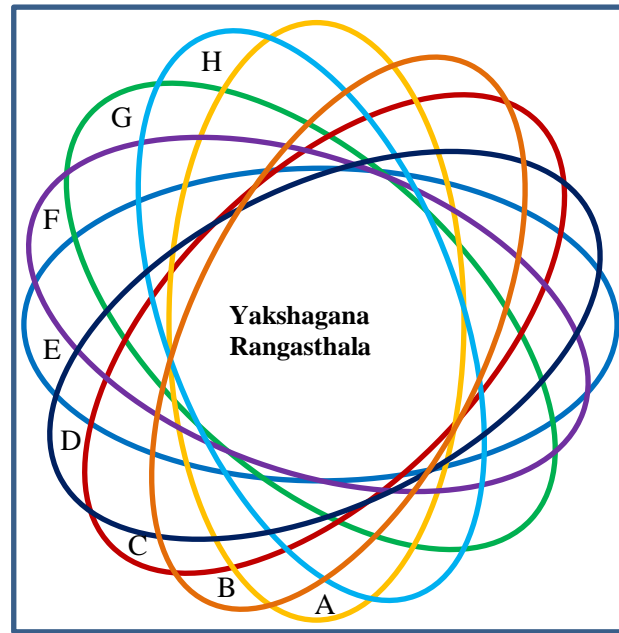


Fig. 3. Yakshagana Venn diagram showing the intersection and union of different art forms blended in Yakshagana.

3. Results and Discussion

Yakshgana has four main components to be followed for the successful execution of the art: They are Chowki, Himmela, Rangasthala and Mummela. For high-quality performance of the art, there should be good coordination between all these components. An important component of Yakshagana is chowki (green room) [Figure 4](#), where artists do their make-up, wear costumes, and fix the *kireeta* (crown), *pagade* (*kedige*, and different types of crowns) ornaments. Depending on the characters assigned. The art has a tradition of getting ready with Ganapati pooja (chowki pooja) before starting the actual performance on *rangasthala*. After *pooja bhagavata* seeks god's permission (symbolic) to start the action on *rangasthala*. [Figure 4](#) shows the typical chowki active scene. The typical *Ganapati pooja* song will have an impact as a pre-performance exercise or a warm-up for all artists. The speciality of Yakshagana is that each artist has to do his own make-up, wear his own costumes, and do the complete *veshagaarika* (complete dressing and make-up) himself. Otherwise, he or she will not be considered a professional artist, or he/she is not fully trained to be an artist. There will be minimum help from a helper just for tying, tightening, seeing the balance of wearings and holding the things/dresses. All these activities behind the stage are also a kind of psychological energy stimulant (exercise) for the artists to perform as a group with momentum.



Fig. 4. (a) Yakshagana chowki; (b) Ganapati pooja in chowki

One of the principal, vital and driving components of Yakshagana is *himmela* which comprises *haadugarike* (*bhagavatige*, singing) with percussions. There have been many reports and discussions comparing this type of singing with Indian classical Hindustani or Carnatic *sangeeta*. However, it is established that Yakshagana has a unique tradition of music, different from Carnatic or the Hindustani *sangeeta* of India. The music and the story depicting lyrics are based on ragas, which are characterised by rhythmic patterns called *mattu* and *tala*. It has its own traditional classicality, *raga*, *laya*, *shruti*, *talas*, *swara* compositions, *aalap*, improvisation sequence, and beats multiplications for dancing. The lyrics based on raga tell the story and the situation. Because of these scientific reasons, we propose it is better to name it “Yakshagaani” *sangeeta*. However, in recent years “Hindustani-Yakshagani Jugabandhi” (dual) performances are becoming more attractive in coastal districts of Karnataka. Our observations and analysis based on the artist’s interview clearly showed that the typical Yakshagaani *sangeeta* with percussion deeply influences the artist’s performance. Scientifically this acts like a stimulant for an emotional performance.

The next equally important and dynamic component is the Rangasthala. Yakshagana is a very rich theatre art form with limited theatrical accessories. Hence, we observed that many engineering skills are being implemented/demonstrated (through expressions and body language) during the performance of Yakshagana without violating the classical basics and tradition of the art. A wooden chair or bench becomes the throne, chariot, garden bench, cot, hunting location, tree, hilltop, and the litho to be used in the forest, depending on the situation. The stage (*rangasthala*) can become a palace, *darbar* (*oddolaga*), *antahapura* (royal bedroom), forest, river, lake, garden, *patashala* (*gurukula*), *yaaga shaala* (*yajna kunda*), *swayamvara* place (marriage hall), a battlefield, a sea shore and a crematorium, a cave, all at once. All these striking impressions are created through the emotional songs (*pada*), *raga*, music, dance, and creative expressions well supported with make-up colours and costumes. Recently lighting effects are also being used. Figure 5 shows the typical *rangasthala* and a close view of the performers.



Fig. 5. Shows the (a) Square type *rangasthala* and (b) Closer view of the performers on *rangasthala* (sitting Krishna as charioteer, Arjuna standing on *Ratha*).

The Yakshagana *rangasthala* (stage) has a defined dimension and shape. Typically it is about 18x18ft square; some troupes also use curved front sides (Figure 2). This is helpful for executing the dance, dialogue, and discussion, covering the entire stage with varieties of steps (*kunitas*) during clockwise rotational dance movements for the artists in sequence. Artists improvise the dance in each round with a definite rhythm with new steps and expressions. During each round trip, the artist performs new steps and new expressions, giving the impression of gaining energy during each round. This we have compared with round-trip gain in a laser cavity having been pumped up each time either with optical, electrical or chemical energy, which is well explained in basic laser physics [24]. Here *rangasthala* is like a cavity, rhythmic repeated round *kunita* is round-trip time, and emotional singing with percussions is the pumping energy. Another vital, heart, and most appealing component of Yakshagana is the Mummela.

The characters with glittering costumes and make-ups perform *kunitas* and expressions along the *raga*-based singing. There is a lot of mathematics and stage engineering involved in executing *kunitas*

keeping the *laya* (rhythm), *tala* for lyrics (based on *raga*), *kunita* steps (doubling sequence), improvisation of *kunitas* and giving *muktaaya* (ending) to *pada* (song). All these depend on the artist's skill, experience, capacity, energy and chemistry between *bhagavata*, percussionists and co-artists. The arithmetic involved here will help decide the step size of the *kunita*, body movements, maintaining the rhythm and covering the entire stage (*rangasthala*) and accommodating the co-artists to perform in sequence. In some situations, there will be ten *mummela* performers at a time on *rangasthala*, depending on the story and the characters required. They adjust the stage cleverly during the in-situ creative performance without hitting or crossing each other, allowing other characters to perform in sequence. This is an undefined but well-executed engineering of the stage utility, spontaneously demonstrated by the artists. In recent years, artists (troupes) have developed the skill of adjustment, greater flexibility of performing with minimum stage dimension and arrangements without violating tradition and classicality and not compromising other crucial performance parameters. This demonstrates the architectural in-situ engineering skills of the artists to utilize the available stage area (*rangasthala*) fully. Apart from knowing the stories and associated sub-stories of Indian epics Mahabharata, Ramayana, and Puranas, the Yakshagana artists are generally well versed in the story, literature knowledge, music, sanskrit, and philosophy. These are essential for their oratory skill development and timely usage of sanskrit shlokas during scholarly discussions. It is common for actors to get into extended philosophical debates or arguments without falling out of character or the story. The *taala-maddale* form is mainly utilized to improve their oratory skill. Traditionally female characters are played by a male. Though this traditional art form was forbidden for women at one time, now the situations have changed, and many women artists are becoming professionals. Currently, there are many ladies Yakshagana troupes in action, and they play all characters, and co-performing teams are also in action.

In Yakshagana, immediately after the improvised dance performance, the artist has to start the dialogue or discussion based on the lyrics of the *pada* (song) depicting the story. This needs stamina and physical energy as the emotions and expressions of the story (*prasanga*) are already created on the stage. Hence there is no time or chance for relaxing. The science behind this continuation of the performance without showing fatigue is that the dialogue will be started on the same *shruti* or pitch of the ending (*muktaya*) of the *pada* (singing). If the artist cannot hold on to this *shruti* and pitch, tiredness can be observed in his dialogue delivery. This biology is very tricky for the performers for comfortable breathing without showing tiredness due to dancing, keeping the story's expressions/dialogues/discussions intact for continuation. All these flexibilities, capabilities, in-situ stage adjustments, and spontaneous creations, without violating the classicality, traditions, and classical frames of the art, can be observed only in Yakshagana. These multifaceted performance creations, flexibilities, and coordination between *himmela-mummela*, and music-dance-dialogue-discussion cannot be observed in any other art forms. Depending on the actors' ability, creativity and experience, there will be variations in dances as well as the depth and duration of dialogue/discussions.

Similar to *Ganapati pooja*, *mangala* (closing) is the other ritualistic closing of the performance. After the story is concluded, the street *vesha* (female character) performs the *mangala* dance, and the *bhagavata* seeks the audience's permission to sing the closing song. Songs in praise of mother goddesses, Shiva, Vishnu's incarnations, and local deities are sung again in the chowki. That completes the entire performance of the day. These observations clearly show that a lot of science and engineering is involved in training, executing, performing, longevity and achieving the high-quality performance of Yakshagana without violating its tradition and classicality. To summarize, our study clearly shows that Yakshagana is a powerful media to propagate humanity, family, religious and moral values, justice, the injustice of life, social equality and balance, entertainment, agriculture, environment and business using the stories of Ramayana-Mahabharatha projected through glittering *vesha-bhushana* (costumes), stimulant music-percussion, dance (*kunita*), expression and dialogues all embedded in it. Hence it is an "all-in-one" form of performing art with many science and engineering aspects to understand.

4. Conclusion

In conclusion, for the first time, empirical mathematical models have been proposed to study and understand the "all-in-one" theatre art, Yakshagana, scientifically. Our observations clearly show that one of the sources of stimulating psycho-physical and emotional energy for the artists for long-duration performance and sustainability is the typical high-pitch music (*bhagavati* and *tala*)

accompanied by the percussions, specifically *chande*, *maddale* and *shruti*. The other source is the *kunitas*; associated breathing patterns help practice yoga and emotional expressions. We expect that these observations will be very useful for further study of the effect of music on the performers' biology and analyse of the origin of stimulating energy, sustainability of the performance and longevity. A non-dimensional equation is proposed to estimate (gauge) the overall performance (index or rate) of the art on a particular day and can be extended to the yearly performance rate of the touring troupes (melas). A Venn diagram has been created to show how different art forms are blended in Yakshagana, and this demonstrates that Yakshagana is a unique "all-in-one" Indian theatre art form that can be called super-art. The main components of the art are discussed from a scientific perspective. It has also been shown that many components of Yakshagana can either be explained using physics fundamentals or compared with principles of physics. The role and importance of coordination between the four main components for successful execution and high-quality performance have been discussed from an engineering perspective. Thus, we conclude that Yakshagan is an art involving a lot of science and engineering aspects. The contents of this article will help open further scientific research on not only Yakshagana but also on other Indian performing arts

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