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A study on socio-economic transformations of post mine closure land in the State of Goa

Mining sector contributes to the state in the form of state exchequer and foreign exchange, employment and physical development; however, in the other hand leaves environmental and socio-economic footprints in the societies. Therefore, it is imperative to develop mine in sustainable manner with implementing an appropriate mine closure plan early in the process of mine development throughout in all mine planning stages keeping in view of the post mine closure socio-economic need of societies and bio-diversity. In this paper, the post closure sustainable alternatives in the state of Goa were explored by transforming the mining activities into the long term prospective with improved environmental conditions even after cessation of mining activities. The criteria are selected based on the ecological, socio-economic and the cultural aspects by considering sustainability and spatial planning. The desired alternatives for post-mining land use are arrived by examining the relations between criteria and alternatives with the help of mathematical tool - Analytical Hierarchy Process (AHP). The results show, the support to the eco-tourism and restoration of the ecology are the priority alternatives of the post-mining land use utilization.

Keywords: Sustainability, mine closure, post-mining alternatives, Analytical Hierarchy Process (AHP)

1.0 Introduction

Mining is known to be a basic industry sector after agriculture (Gayana and Chandar, 2018). Mining, especially opencast mining, is a short-term phenomenon – a temporary land use, has long lasting impacts on landscape, ecology and on the livelihood of local population (Mishra, Singh, Priyadarshi and Singh, 2017). The selection of the mineral extraction method is varied depending mainly on the configuration of the deposit (e.g., shape, size, depth, extent) (Didier, et al., 2008). Mining regions are categorized by lack of demographic instability, economic diversity, growing health issues, geographical isolation and dependency on the mining companies and the non-appearance of alternatives for economic development in diversified pattern (Bebbington, 2018). In the past, mines were seen to be closed without appropriate planning including assessing the impacts on the community and were ineffectively regulated by either the proponent or the government (Cowan W., 2010). The outcomes of mine closures is still essential to be addressed by the mining industries for varities of environmental and social aspects and to mitigate the unwanted outcomes which may occur on closure; this includes the assurance of compensation received by the residents of mining area and their appropriate settlements (Haggerty, Haggerty, Roemer and Rose, 2018), restoration of a feasible ecosystem that is for healthy and safe (Qi, Fourie, Chen and Zhang, 2018), and the reasonable handling of liabilities and assets (Sinding and Peck, 2009). Mine closure may result from various reasons. Closure of a mine may be caused from several reasons. Closure caused by depletion of resources may be defined as matured closure, while closure of mine caused by social, economic or policy reasons is termed as premature closure (Laurence, 2011). The term sustainability is crucial for a straightforward cause: the Earth's ecosystems and the quality of life 'prosperity cannot be maintained if it is not maintained (Szabo, Szádoczki, Bozóki, Stãnciulescu and Szabo, 2021). Therefore, sustainability is derived as one of the world's fundamental objectives, for establishing the policies and treaties and driving the vision for sustainable development in worldwide (Szabo, Szádoczki, Bozóki, Stãnciulescu, & Szabo, 2021).

1.1 Mine closure

Mine closure practices principally began developing in the latter half of 1960s and early 1970s in countries having advanced economies and mature mining industries (Limpitlaw and Briel, 2014). In India, the mine closure plan has been administered by the Central Government vide Notification No. GSR 329 (E) dated 10.04.2003 and No. GSR 330 (E) on 10.04.2003. Mining does not necessarily mean a permanent loss of land for other use, on the contrary it holds potential for altered and improved use apart from restoring the land for agriculture, forestry and irrigation (Mazumdar and Kulkarni, 2016). Mine closure is the ultimate phase of the mining cycle

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that consists of the cessation of operations, reclamation of mine sites, including the rehabilitation of environmental and social damages, and site relinquishment (McHaina, 2001). According to (Blanchette and Lund, 2016) mine 'closure' is the procedure of reassigning responsibility for mined out lands from the mining company back to the state, in order to the safety criteria on the company that must be achieved in accordance with state and/or national legislation, which differs world-wide. Ideally the mine closure planning should begin with the project conception itself. Mineral conservation and development (MCD) rule,1988/2017, states that "mine closure process is a continuous series of activities starting from day one of the initiation of mining project with the two types; namely: progressive mine closure plan and final mine closure plan". A mine closure plan is a document that provides guidelines to the mining industry and the other related stakeholders, creates closure objectives and designates the actions to be taken to attain them (Sánchez, Silva-Sánchez and Neri, 2014). The greatest elementary goal of mine closure is to reduce forthcoming financial risk of the company's shareholders by reducing the future environmental impacts due to the mining activities (Garcia, 2008).

It has been observed that establishment of ecology and recreational activities like parks, ponds, fountains, worshipping places and other recreational infrastructures over mined out degraded land would serve the purpose of development of ecotourism in the area and restoration of the degraded mined out land/OB dumps (Singh, Gangopadhyay, Raju, Ranjeev, Srivastava and Kumar, 2017). Ecological restoration is a process of assisting the recovery of the structural and functional components of an ecosystem which has been destroyed or degraded due to various anthropological activities over a due course of time (Singh, Gangopadhyay, Raju, Ranjeev, Srivastava and Kumar, 2017).

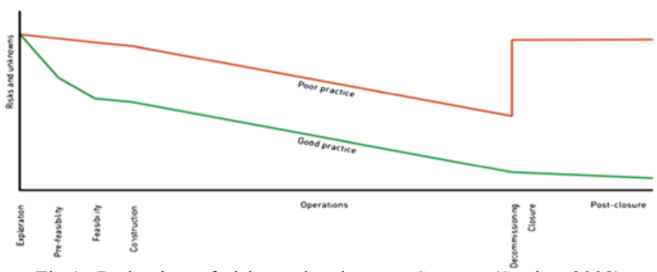

Fig.1: Reduction of risks and unknown. Source: (Starke, 2008)

Although a substantial requirement to better comprehend the social aspects of mine closure has been recognized across the industry, there is a dearth of case studies that cover the post-closure outcomes in long-term (Svobodova, 2019). It is implicit that mining always gives foot prints three axis i.e., social, economic and environment during each stage of construction. Therefore, it is imperative to develop mine in sustainable manner with implementing an appropriate mine closure plan early in the process of mine development throughout in all mine planning stages keeping in the view of post mine closure socio-economic need of societies and bio-diversity. The aim of the current study is to assess the post-mining land use in the Indian paradise State Goa by transforming the activities into the long term prospective with the improved environmental conditions even after cessation of mining activities.

1.2 About the study area: Goa

Goa is a statehood having the true combination of natural beauty, history, culture, and with beauty of climate to attract tourists, who have placed it prospective impact on both the international and national tourist map (TERI, 2012). The key economic activities of the people in the state are tourism, fishing, agriculture, and mining (Arondekar & Murthy, 2017).

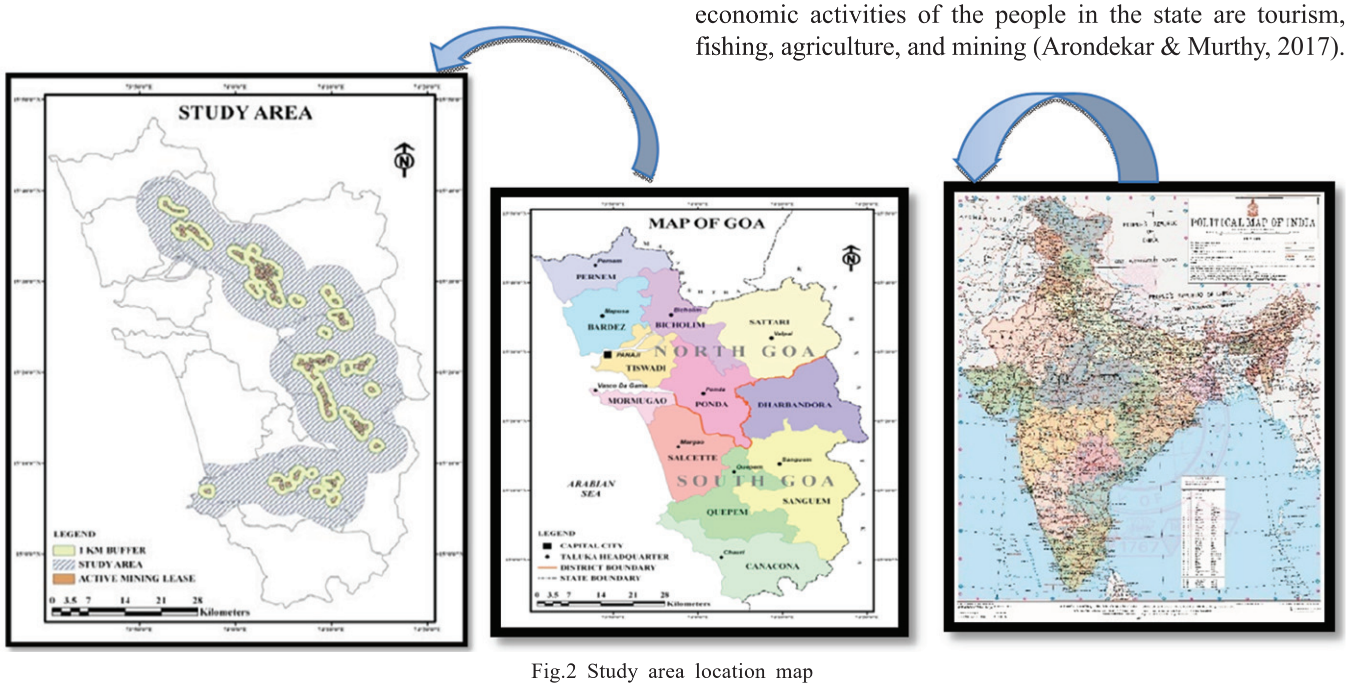

Fig.2 Study area location map

Despite the presence of iron ore in Goa discovery by European was of a Dutch traveler (in the 16th century); it took substantial periods for the then Portuguese rulers to start the mining of iron ore in Goa. The grant of several mining concessions was commenced by the decree of laws in September 20, 1906 (Chhibber, Rogers and Milkereit, 2011). However, it was in 1947 when the exportations of the mineral started and swiftly developed as the key economic activity. It was in 1987 when the Indian government took steps for converting concessions into leases, through enacting the Goa, Daman and Diu Mining Concessions in the Indian Parliament (Abolition and Declaration as Mining Leases) Act 1987 (Chhibber, Rogers and Milkereit, 2011). Quepem and Sanguem in South Goa and Sattari and Bicholim in North Goa are the major four talukas that fall in the mining belt. According to the Mineral Yearbook published by Indian Bureau of Mines (IBM) in 2019, the reserves/resources of hematite (UNFC system), as on 01/04/2015 was recorded as 1,189 million tonnes and 266 million tonnes of magnetite.

Although the mining sector contributed considerably to the states GDP from 9.36% in 2006-07 to 19.87% in 2010-11 it had also had seen adversative impacts on the environment in the mining belt (Arondekar and Murthy, 2017). In the context of Goa, the state has seen two phases: one, a drastic growth in the mining operations to meet the growing demand from China in the last decade; secondly, a sudden and unexpected ban in the mining operations subsequent to the Supreme Court Order in September 2012 and in February 2018. The mining ban affected the economic status of the households in the mining areas in such a way that the households that had massive loan installments' could not meet the same as they lost their principal source of income (Naik, 2017). This indicates the inconsistency in the mining activity to give sustainable source of income to the society and to the State. Therefore, a dreadful need for sustainable mining and their closure as to support the dependent community and the economy of the state even post closure phase of a mine, with conserving the ecology and the environment of the area.

In this paper, an effort to explore the sustainable alternatives for the post closure of mine by transforming of mining activities into the long term prospective with the improved environmental conditions even after cessation of mining activities.

The draft structure of the paper is represented in Fig.3:

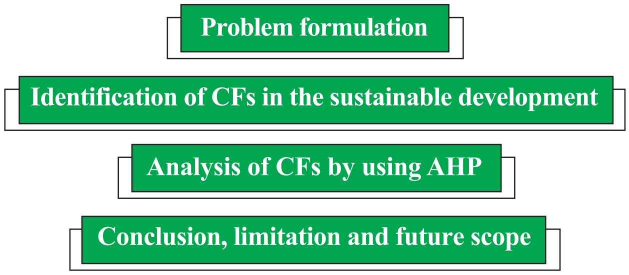

Fig.3 Draft structure of the paper

2.0 Research methodology

Analytic Hierarchy Process (AHP) was initially developed by Prof. Thomas L. Saaty (1977) is a model that helped the decision makers arrive at the most logical choice. It is one of the most commonly used multi-criteria decision method as it provides to model a complex problem in a hierarchical structure showing the relationships between the goal, criteria, sub criteria and the alternatives, giving in a wide-ranging view of the problem for decision makers (Szabo, Szádoczki, Bozóki, Stãnciulescu and Szabo, 2021). The advantage of AHP is that it is able to check and decrease the inconsistency of judgments of the experts. This is particularly true in the instances when more than one or many experts are invited to make a judgment (Abdullah and Pang, 2016). Multi-criteria decision analysis is an satisfactory approach toward sustainability issues, being an efficient tool "to implement a multi/inter disciplinary approach" (Munda, 2005). Analytic Hierarchy Process (AHP), have been used in connection with sustainable development in many different fields, for instance, in the mining industry (Shen, Muduli and Barve, 2015) in agriculture (Rezaei-Moghaddam and Karami, 2008), in electricity generation (Ahmad and Mat, 2014), in flooring systems (Reza, Sadiq and Hewage, 2011), in strategic planning, and management of companies (Calabrese, Costa, Levialdi and Menichini, 2019), in environmental problems (Gómez-Limón, Arriaza and Guerrero-Baena, 2020), in smart city (Myeong, Jung and Lee, 2018), in energy management (Cheng, Mo, Tian, Xu and Xie, 2019) and in well-being (Hienuki, Noguchi, Shibutan, Saigo and Miyake, 2019). This clearly illustrates the versatility of the AHP and its applications. In this study, the AHP is applied for the prioritization to select the strategic factors for sustainable mine closure with the following main steps:

Step 1: Identificati\on of post closure land use opportunities

In this research, the four criteria such as technical, environmental, economic and social are selected based on the definition of International Council of Mines and Metals for sustainable development in the sector. The preferred alternatives for utilization of post-mining land are evaluated through the Analytical Hierarchy Process (AHP) method by analyzing the relationship between four criteria and their sub criteria to find out the critical factors (CFs) of the alternatives. The underlining criteria's such as technical, environmental, economic and social are established as defined in the International Council of Mines & Metals for sustainable development in the sector and the sub criteria (alternatives) are further selected based on the regional consideration of sustainability and spatial planning. These criteria are further classified into sub-criteria based on the global standard and in the regional requirements as shown in the Fig.4. The primary objective of this analysis is to identify these key strategic factors.

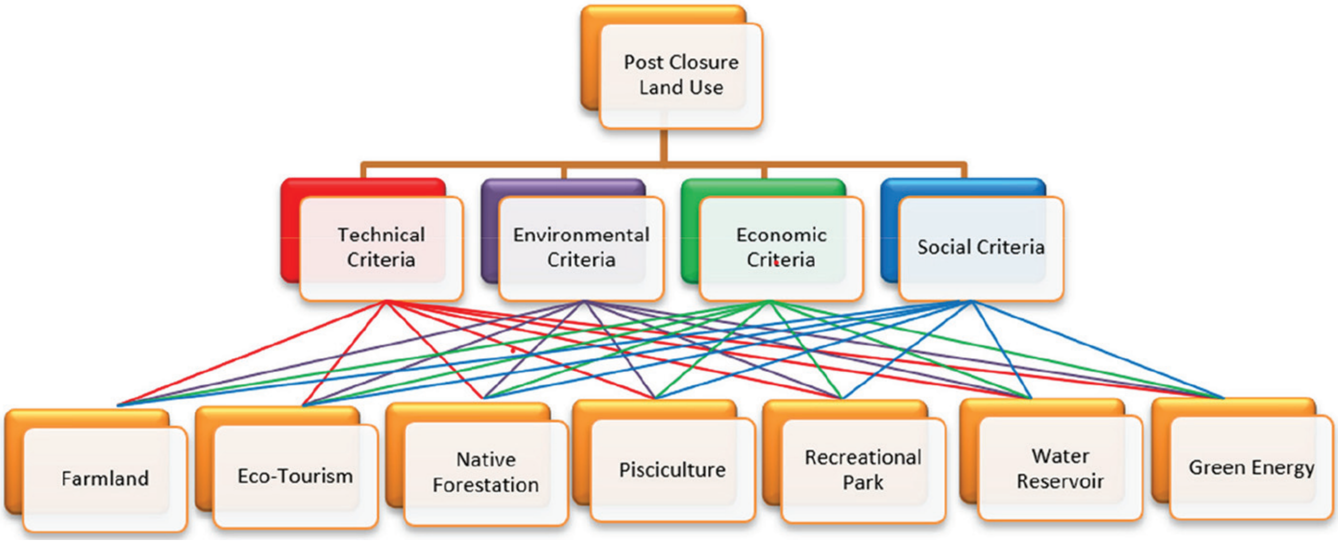

Fig.4: Structure of post closure land use

Step 2: Data collection via expert rating

These sub-categories are weighted and scored by using a qualitative scale in a questionnaire whose numerical values are given in Table 1 by the experts based on their experiences and field of work.

Step 3: Construction of decision matrix

This paragraph constructed a square matrix by introducing the pair-wise comparisons of all the criteria (alternative) are used. The components in diagonal of the matrix are 1. The configuration in general of decision matrix is shown in equation (1). The decision matrix is formed by taking geometric mean value of all the five experts' decisions; which are given in Table 2.

$$A = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{pmatrix} \qquad (1)$$

Step 4: Normalization

This step is used to normalize the matrix by totalling the numbers in column wise. Then, each entry in the column wise is divided by the corresponding column sum to produce its normalized score. Here, the sum of each column is 1; which are given in Table 3.

Step 5: Consistency analysis

In this step consistency ratio is calculated and its values are checked. The purpose of this step is to check the consistency of the individual expert ratings. If CR, is 0.1 or below (CR<0.1) then, it is considered to be acceptable (Saaty R.W., 1987). Following steps are essential for evaluation of CR:

- The pair-wise comparison matrix of each column is to be multiplied by the corresponding weight.
- Sum of the row entries is divided by the corresponding weight.
- Average of the values is computed from above steps and it is denoted by λmax.
- $\mathrm{CI} = \dfrac{\lambda max - n.}{n - 1}$
- Then, consistency ratio is calculated as: C.R.=CI/RI (where RI is a random index).

TABLE 1: LINGUISTIC VALUES WITH THEIR CORRESPONDING NUMERICAL VALUES FOR AHP ANALYSIS (SAATY, 2008)

Intensity of importance	Definition	Explanation
1	Equally importance	Two activities contributed equally to the objective
2	Slight or weak	Middle values reflected fuzzy inputs
3	Moderately importance	Judgment and experience slightly favour one activity over another
4	Moderately plus	Middle values reflected fuzzy inputs
5	Strongly importance	Judgment and experience strongly favour one activity over another
6	Strongly plus	Middle values reflected fuzzy inputs
7	Very strongly importance	An activity favored very strongly over another;
8	Very, very strong	Middle values reflected fuzzy inputs
9	Extremely strong importance	Highest possible order of affirmationof the activity.

Table 2: Pair-wise comparison matrix of the geometric mean value of experts rating

	Criteria	C1 Ecotourism	C2 Pisciculture	C3 Recreational park	C4 Water reservoir	C5 Green enerty	C6 Township	C7 Native aforestation	C8 Farm land
C1	Ecotourism	1.00	1.15	1.14	1.06	1.11	1.32	1.03	1.24
C2	Pisciculture	0.87	1.00	1.00	0.93	0.97	1.16	0.90	1.09
C3	Recreational park	0.87	1.00	1.00	0.93	0.97	1.16	0.90	1.09
C4	Water reservior	0.94	1.08	1.08	1.00	1.05	1.25	0.97	1.17
C5	Green energy	0.90	1.03	1.03	0.95	1.00	1.19	0.93	1.12
C6	Township	0.76	0.86	0.86	0.80	0.84	1.00	0.78	0.94
C7	Native aforestation	0.97	1.11	1.11	1.03	1.08	1.29	1.00	1.21
C8	Farm land	0.80	0.92	0.92	0.85	0.89	1.06	0.83	1.00

Table 3: Normalization matrix of post closure alternatives of the expert's decision

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
C2	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
C3	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
C4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
C5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
C6	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
C7	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
C8	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Table 4: Random inconsistency indices for n=10 (Saaty R.W., 1987)

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Where, n = order of matrix

Table 5: Expert wise consistency ratio (C.R.)

	Consistency ratio (C.R.)	Consistency Check
Expert 1	0.058	
Expert 2	0.065	
Expert 3	0.063	C.R.< 0.1
Expert 4	0.063	
Expert 5	0.004	

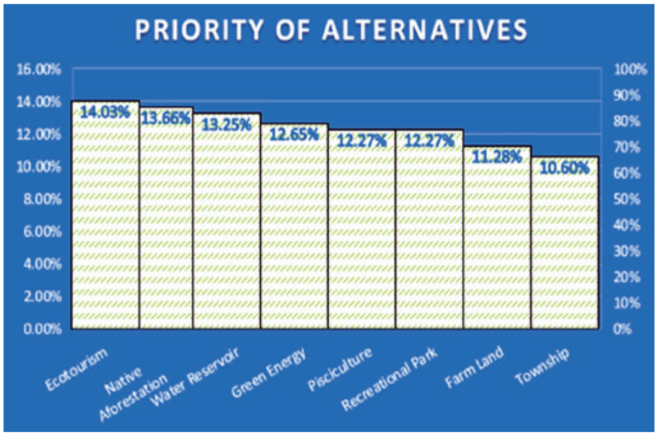

Fig.5: Priority of post closure land use alternatives

Consistency ratio (CR) from the judgments of all the five experts for the sub-criteria are evaluated by using the above procedure; which are given in Table 4.

Since, CR<0.1, therefore, the judgments of the experts are considered as consistent and henceforth pair-wise comparison matrices are acceptable. Therefore, process is sustaining for evaluating the final priority or ranking of criteria.

Step 6: Priority/rankings of criteria

In this step, criteria are ranked with respect to their corresponding weights to determine the final ranking/priority of the criteria (alternatives). The final priority of alternatives is represented in Fig.4.

3.0 Conclusions

Sustainability is the vital components for the quality of life and the prosperity in the Earth; therefore, sustainability is one of the world's fundamental objectives for driving the vision and establishing the strategies for sustainable development in worldwide. The planning and implementation of land reclamation and mine closure in wider perspective of post closure use can contribute revenue to the regions.

The current study analyses the sustainability of mine closure by using the mathematical tool, Analytical Hierarchy Process (AHP) in the state of Goa, India. The result of analysis shows, support to the eco-tourism (as an upcoming tourism sector in Goa) and restoration of the ecology are the priority alternatives of the post-mining land use utilization followed by the alternatives water reservoir, green energy, pisciculture, recreational park, Farmland and township, which are represented in Fig.4. These transformations will minimize the negative impact of mining footprints and will create the sustainable source of income to the society by conserving the ecology of the area in long prospective.

Limitations and further Scope

Present study analyses the post closure aftermath to the society after implementation of systematic and scientific closure of mines in non-forest region only. The study analyses the post closure alternatives by applications of the mathematical tool, Analytical Hierarchy Process (AHP), constructed on the experts' judgments. The future study in broad with involvement of larger samples size in clubbing with spatial planning is envisaged.

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