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Research Article

Optimizing Agricultural Labor Management In India: A Mobile-Based Approach For Efficient Workforce Allocation

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ABSTRACT

The movement of labor resource has a wide range of impacts on agriculture, including productivity and the organization of labor. Inevitably, overheads such as job search and communication in agricultural labor markets are not well structured and job allocation is rarely done effectively. This problem is most evident in rural areas where farmers are unable to find suitable workers and potential workers do not know where to go to look for the jobs that are appropriate for their skills. To this issue, the application developed attempts to streamline these problems by providing effective management of labor resources and increasing productivity. The application allows the posting of jobs including tasks to be done, deadlines, and payment details as well as searching for jobs by workers that fulfill their skills and added preferences. With the help of geolocation services, the app allows the scheduling of a workforce across several farms to ensure even distribution of labor resources. Improved in-app communication features and secure payment services increased users' confidence, improved interactions and made it easier to find jobs. In this way, this model offers seasonal workers to the agricultural industry whilst allowing for its sustainable development in the future.

Keywords: Labor management in agriculture, Agricultural productivity enhancement, Mobile application in agriculture

1. Introduction:

A large section of the workforce in India is confronted with long-term difficulties due to a combination of poor pay, unstable work, and inadequate skills. Agricultural workers face hazardous working conditions, with an estimated 170,000 killed each year, and millions more injured or poisoned by pesticides and other agro-chemicals. Social marginalization, which mostly affects members of underprivileged castes and tribes, makes this situation worse. In this particular setting, the lack of strong social security measures exposes these laborers to potential abuse and long-term misery. The urgent need for broad actions to improve the conditions of India's agricultural labor force is highlighted by this study. The objective is to identify the factors that contributed to poverty reduction in certain countries and to suggest measures to improve the socio-economic conditions of agricultural laborers. It promotes a comprehensive strategy that includes enacting policies to improve working conditions, expanding employment possibilities, fortifying legal protections, and giving workers more negotiating power [1].

Since 1991, the percentage of jobs in India within the agricultural sector has been on the decline, with 42.86% of the populace working in the sector by 2022. Rather, it underscores the concern about the reduction of agricultural employment even when the sector is still critical to the economic strategy. Digital agriculture solutions are either un-thought-of or unattainable by smallholder farmers and other marginalized communities in India as they face issues of low digital literacy, affordable ICT infrastructure, understanding language and high software and subscription costs. Apps such as Kisan Suvidha and IFFCO Kisan enable the users to receive information about market prices, weather forecast, and government programs for informed decisions. However, very often it is the case that issues of coverage and lack of digital literacy skills is what detracts from the full utilization of these solutions [6]. ICT will empower farmers by providing them with necessary information, help in decision making and increased productivity [13].

2. Literature Survey

Labor management systems (LMSs) are one of the advanced legacies targeted for the enhancement of the actual effective management of the human resources of agricultural personalities. Several tools are incorporated in these systems which include cost estimation, time tracking, record keeping, payment management, staff utilization schedules and communication as well as staff training. FLMS enable farmers to shift scheduling and payroll processing hours to other valued activities, this enhances efficiency as well helps saves cost. They also enhance the allocation of human resources to farmers however reduces risks of labor related accidents. This is because it helps the farmer to respect labor laws by paying the laborers decent wages that are supported with records of proper documentation for hours worked. There co-ordinates the challenges of the market for a number of farm labor management information systems but the choice of the one that is comfortable is affected by certain factors including the number of people working, the area covered by the farm, and others. Research suggests that adding AI-driven analytics, real-time expert access, and offline functionality can enhance decision-making and accessibility for remote farmers, bridging these gaps and providing a more comprehensive agricultural management tool [11].

According to the Social Impact Study FLM farmers, the farmers stand to benefit greatly, the farmers want an intuitive application, taking that into account these advantages, economists stated that there and their time is being wasted. Allegedly, the NITI Aayog Discussion Paper (2022) observed that there were significant workforce dynamics in India. It is still agriculture which occupies a considerable share of the workforce despite falling share in the GVA of the country [3]. Agriculture was only 18.29% of the GVA generated in 2019–20 but it employed a majority 45.6% of the total workforce, indicative of a bulging disproportion [3].

Owing to the development of AI and data analytics, new possibilities for labor management in the agricultural industry are appearing. Similarly, just as AI is changing the way crops are monitored, it can also be applied in labor distribution and workforce optimization. For example, the CropDeep project illustrates the power of AI to process complex agricultural data, such as the stages of crop growth, using advanced models like YOLOv3 and Faster R-CNN, with a classification accuracy rate of over 99 percent[7]. Concerning labor management, AI and predictive analytics could allow evaluating patterns to help match labor supply with demand in response to seasonal changes and task requirements. However, as with precision agriculture, which requires the use of specialized annotated datasets, labor management processes have problems with data availability and consistency, to put it mildly, across diverse contexts and heterogeneous labor requirements [7]. Changes encompassing the integration of mobile applications and IoT devices to address the challenges of real-time data updates on labor demand, skills, and workload can facilitate an effective and flexible labor management model in the agricultural sector [7].

2.1. Current Technologies for Agriculture and their Limitations:

The adoption and application of modern agricultural labor management systems might be impeded by physical geography for farmers, especially those residing in distant or underprivileged places. Often, the primary reason for this is the obvious cost. This could be due to overstated expenses, inadequate services, or a lack of knowledge about current technology. Furthermore, less wealthy farmers and those with limited resources may find it difficult to maintain and repair such systems. Another possibility is that the cost of the software, hardware, and recurring subscriptions is just too high. Additionally, because many of the systems have complicated learning curves for individuals who are unfamiliar with them, farmers would find it challenging to utilize them to their full potential. Some of the existing applications are:

- Kisan Suvidha
- Pusa Krishi
- IFFCO Kisan Agriculture
- APEDA Farmer Connect

Limitations of the existing Applications: For other farmers, digital literacy is a major obstacle because they might not be comfortable or skilled at using cellphones or mobile apps. This restriction may make it more difficult for them to get access to and make use of technical tools meant to improve agricultural practices or obtain important information. Language hurdles further make the situation more difficult because not all of the apps created for agricultural use are available in all of the languages that farmers in India speak. Due to the linguistic divide, digital solutions are less accessible and effective, which emphasizes the necessity of inclusive design and language localization to guarantee fair access to technologically advanced agricultural resources [2,12]. While mobile apps have enabled delivering agricultural information and guidance, they have yet to reach their full potential in optimizing farm productivity. Limitations in Farm-n-pedia and similar programs, such as lacking personalized, real-time advisory assistance tailored to regional circumstances, along with missing predictive analytics, have left needs unmet for farmers with diverse challenges [10].

2.2. Field Survey

Consequently, certain field study observations concerning farmer-labor interaction technology in India, provide several relevant implications. To begin with, it emphasizes on the extent to which both farmers and laborers are able to access pricing, weather and farming information via mobile phone but extreme mobile phone barrier for

the farm laborers is low literacy level by a score of 4.12 out of 5 [16]. A majority of farmers utilizes the mobile phone to access information regarding pesticide (89.09%), seeds/ sowing (83.63%) and animal husbandry (70%). Moreover, 65.45 percent of the farmers use mobile phones for real time market situation and price information, which demonstrates how knowledge-enabling, tech-savvy mobile agriculture plays to farmers' need for practical information for their daily decisions [17]. There is a distinct shift towards mechanization: a growing number of farmers have begun adopting and utilizing machines for carrying out tasks like harvesting and ploughing as well as more frequently using irrigation and pesticide/fertilizer equipment for better crop yield. The employment of farmer-labor interaction technologies, for example, has favored the transformation of the lives of people who engage in agriculture. There are still large barriers that remain, in particular in the rural areas, such as the nature of the technology that is affordable and the electricity supply. Although it is strongly approved by said development, it increases efficiency and productivity of agriculture in India. It is imperative that other organizations and the government take measures to ensure that the potential of this technology in improving the income and farming practices of the people through its use is realized by provision of financial assistance, education, construction of encouraging systems and sensitization on its usable benefits.

2.3. Outcome

According to the survey's findings, farmer-labor interaction technology is a field that is expanding quickly in India. Many technologies are being employed to raise the productivity and efficiency of agricultural production while also enhancing the quality of life for laborers and farmers. According to the survey, the majority of laborers and farmers use their mobile phones to get information on market prices, weather forecasts, and agricultural methods. Computers and the internet are being used by a large number of laborers and farmers to market agricultural products, manage farm records, and obtain agricultural information. An increasing number of farmers are using machinery to carry out agricultural operations like planting, harvesting, and plowing. Farmers using digital extension services saw about an 18% increase in crop productivity and a 25–29% increase in crop income which in turn helps the farmers match with the laborers [18]. More and more farmers are using irrigation systems to supply water to their crops. An increasing number of farmers are using pesticide and fertilizer application systems to increase the effectiveness of their use of these substances.

3. Problem Formulation

In the agricultural industry, employers frequently have trouble hiring trustworthy workers for their farms, and jobless workers also have trouble finding positions that fit their needs. The labor market becomes inefficient as a result of this mismatch between farmers and laborers, which can lower farmer production and revenue and increase laborer unemployment.

However, available work in the non-farm sector can still be limited with better-paid occupations likely being filled by individuals from the non-disadvantaged social group, and with higher education standards hence showing that rural employment policies for the disadvantaged must be developed. Despite, a marginal decline in the rural poverty rates in India with these disparities by regions, agriculture and agriculture related jobs remains the major source of working population particularly those without education and beneficiaries of the backward castes. This high level and persistence in agricultural labor speaking volume for it as the last resort of employment in rural areas [15].

First, it's important to recognize the diversity of the farm labor pool. Because skill level, regional differences, and crop variety can all have a big impact on compensation needs, the system should take these things into consideration. Including inflation-adjusted actual wage computations is crucial, as well. This makes it easier to understand a worker's purchasing power and aids in the decision-making process regarding pay. Third, monitoring or combining data on social security benefits provided to employees may be helpful if the system's goal is to enhance farm labor practices. Fourth, it would be worthwhile to investigate productivity measuring possibilities. Better performance might be encouraged by tying wages to output, depending on the management style of the farm [5].

Moreover, farmers who are eager to relocate to regions with a strong labor demand frequently struggle to find places where their talents are needed and lack information about possible destinations. Their access to better employment possibilities may be restricted and their capacity to make well-informed relocation decisions is hampered by this lack of knowledge. The percentage of employment in agriculture in India has been steadily declining over the years. In 1991, the employment rate in agriculture was around 65% and by 2022, that number had fallen to 42.86% [4].

The recent labor market surveys have indicated that the difference in employment for the agriculture sector as well as the non-agriculture sector has continued to propel. In 2019-20, 60% of all female workers in India were in the agricultures while only 40% of the workers were male[3]. Employment being differentiated by gender suggests some measures will need to be performed that will enhance the working conditions and the available opportunities for female workers in the agricultural sector [3]. AI has been extremely effective in maintaining agricultural chains by helping the farmers to anticipate the market demands and manage the logistics efficiently. It still faces significant barriers such as high costs limited digital infrastructure [9].

It is therefore necessary to develop a mobile application that connects jobless laborers and farms and offers a platform for job matching. The software should also provide advice and insights to farmers looking to relocate to regions with more labor demand, assisting them in choosing appropriate locations. The smartphone app seeks to

solve these issues in order to improve the effectiveness of the agricultural labor market, make it easier for farmers to locate talented workers, give job chances to jobless laborers, and arm them with knowledge to make educated migration decisions.

4.THE PRODUCT'S NEED

4.1. The necessity for the product.

There is no doubt that in the context of Indian agriculture where working physically is important, there is a need for a comprehensive farm labor management system. With this type of approach to managing the workforce, one will also be able to manage the labor resources efficiently and in the process enhance the output levels within the agriculture sector. Moreover, they help the farmers in streamlining the rest of their operations and in increasing the total output by efficient use of labor resources. This is achieved by appropriate task division, focusing on wastage of employment and job positions and other work activities, all which boost agricultural production. In addition, the system helps to ensure efficient use of the resources available and prevent instances where there are more workers than necessary and vice versa by helping to forecast labor requirements accurately depending on the land area and the farm activities undertaken. As a consequence, farmers are able to cut excessive expenditure by minimizing the duplication of efforts, the different phases of the quintuple process removing wasted time, and discovering dormant or operational wasteful activities. Also, integrating technology in coordination of labor falls the barriers of communication between farmers and laborers increasing production efficiency as well as decreasing errors. Keeping track of each worker's attendance, work, and compliance ensures that farmers adhere to labor regulations while allowing the implementation of data supported management decisions. This in turn makes it easy to execute rational plans with respect to resources. Along with IoT, many other technologies like drones and machine learning algorithms are also driving changes in agriculture: serving the three main purposes–providing predictive insights on crop cycles and management; efficiency of resources, allowing for precision farming (a process which optimizes field level management with regard to sunlight absorption, water retention etc.) [8].

In the final analysis, a farm labor management system is beneficial in overcoming the problems associated with labor-intensive farming but also serves as a catalyst for innovations in agricultural technologies which advances sustainability within the sector. In terms of job matching and insights, the proposed mobile application seeks to bridge the understanding qualitatively between a pool of unemployed laborers and the farmers. These software users sensibly enable the farmers and therefore advances the agricultural progress in India by increasing the economy of the agricultural workforce and creating job opportunities.

4.2. Objectives of product

Establishing a platform that conveniently links jobless laborers with farmers is the main goal. This will help the former locate acceptable employment possibilities and the latter effectively meet their labor requirements.

Enhance Agricultural Labor Market Efficiency by saving farmers time and effort in their search for workers and giving laborers access to a greater variety of job options.

Improve Income and Employment Opportunities by linking farmers with knowledgeable workers who can make valuable contributions to their farming operations, the app should help them raise their output and income. In addition, it must to offer job chances to jobless laborers, assisting them in finding employment and making a living.

Facilitate Migration Decision-Making: The app should help farmers make well-informed judgments about possible migration destinations by providing information and recommendations regarding regions with high labor demand and limited labor availability. With the help of this goal, farmers will be able to investigate more lucrative career options and raise their earning potential.

Fostering trust and transparency should be the app's top priority. This may be achieved by including rating and review systems, making sure that laborers and farmers are communicating clearly, and enabling safe and transparent financial transactions. Establishing a dependable and trustworthy community within the app is the goal of this purpose.Enable Users via Personalization: Give users (farmers and laborers) control over their job search and hiring procedures by offering customization choices including job preferences, location filters, and fee setting.

5. Proposed Algorithm and Model

5.1 Algorithm 1: XGBoost Model Training and Evaluation

Data Preprocessing:

Import the necessary libraries for data manipulation and machine learning.

Standardize the numerical features of the dataset D :

$$X'_{numerical} = \frac{X_{numerical} - \mu}{\sigma}$$

where μ is the mean and σ is the standard deviation of the numerical features.

Apply one-hot encoding to the categorical features:

$$X'_{categorical} = OneHotEncode\left(X_{categorical}\right)$$

2 Data Splitting:

Split the dataset D into three non-overlapping subsets: training set D_{train} validation set $D_{val,}$ and test set $D_{test:}$

:

$$D_{train}, D_{val}, D_{test} = Split(D)$$

3 Data Transformation:

Convert the datasets into XGBoost's DMatrix format:

$$DMatrix_{train} = DMatrix\,(D_{train})\; DMatrix_{val} = DMatrix\,(D_{val})\; DMatrix_{test} = DMatrix\,(D_{test})$$

4 Model Training:

Define the parameters for the XGBoost model:

Parameters = {'objective': 'reg:squarederror', 'max_depth': 4, 'lambda': 10, 'learning_rate':0.01}

Train the XGBoost model with early stopping: model = XGBoost.train(Parameters, DMatrix $_{train}$, evals = [(DMatrix $_{val}$, 'validation')], early_stopping_rounds = 10)

5 Prediction:

Generate predictions on the test set: $predictions = model.predict(DMatrix_{test})$

6 Model Evaluation:

Evaluate the model's performance using Mean Squared Error (MSE).

Calculate the R^2 score to assess the goodness of fit.

Results :

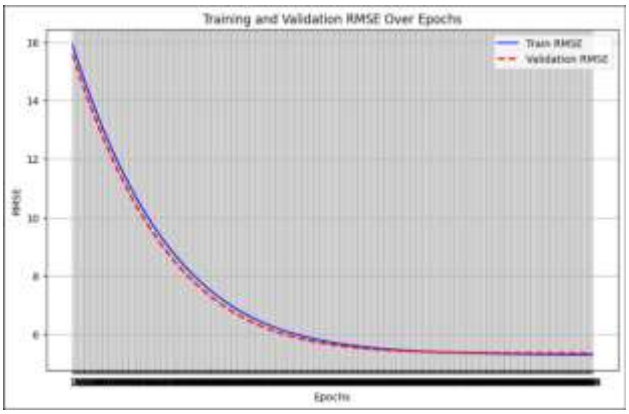

Fig.1-Training vs. Validation RMSE Over Epochs

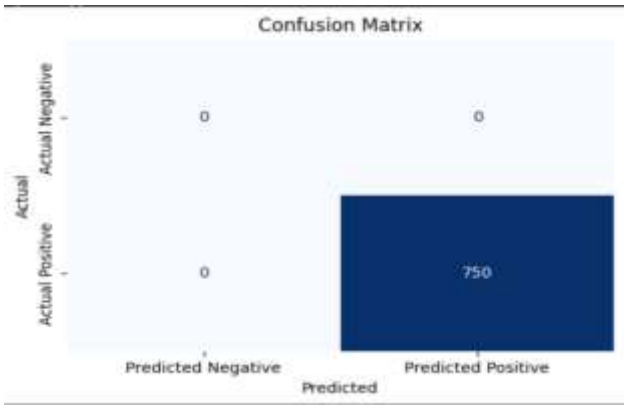

Fig.2- Confusion matrix

5.2.Algorithm: Dynamic Pricing Calculation

For each transaction $t \in T$:

If $t.D \in P_{high}$ and $t.S \in P_{low}$:

Calculate M_D based on $P_{D_{high}}$ for high demand

→ Calculate M_S based on $P_{S_{low}}$ for low supply

→ Set $DPM = max(M_D,$ demand_threshold_low $) \times max(M_S,$ supply_threshold_high).

Else if $t.D \in P_{low}$ and $t.S \in P_{high}$:

Calculate M_D based on $P_{D_{low}}$ for low demand

→ Calculate M_S based on $P_{S_{high}}$ for high supply

→ Set $DPM = max(M_D, \text{demand\_threshold\_low}) \times max(M_S, \text{supply\_threshold\_high})$.

Else:

Calculate M_D and M_S based on median demand and supply values

→ Set $DPM = max(M_D, \text{demand\_threshold\_low}) \times max(M_S, \text{supply\_threshold\_high})$.

5.2.1. Demand Multiplier M_D

The demand multiplier M_D adjusts prices based on whether demand D (approximated by Total_Earnings) falls within high or low percentiles:

$$M_D = \{\frac{D}{P_{D_{low}}},\ if\ D > P_{D_{low}}\ \ \frac{D}{P_{D_{high}}},\ if\ D \le P_{D_{low}}$$

where:

$P_{D_{high}}$ and $P_{D_{low}}$ represent the high and low demand percentiles, respectively, set at the 75th and 25th percentiles of historical Total_Earnings values.

5.2.2. Supply Multiplier M_S

The supply multiplier M_S adjusts prices inversely based on whether supply S meets high or low percentile criteria:

$$M_S = \{\frac{S}{P_{S_{high}}},\ if\ S > P_{S_{high}}\ \ \frac{S}{P_{S_{low}}},\ if\ S \le P_{S_{high}}$$

where:

- $P_{S_{high}}$ and $P_{S_{low}}$ represent the high and low supply percentiles, set at the 75th and 25th percentiles of historical

5.2.3. Dynamic Pricing Multiplier DPM

The final **Dynamic Pricing Multiplier** DPM is determined by combining M_D and M_S with pre-defined threshold constraints, ensuring the multipliers remain within the desired range for stability:

DPM=max(M_D ,demand_threshold_low) x max(M_S ,supply_threshold_high)

where:

- demand_threshold_low is a predefined minimum multiplier for demand.
- supply_threshold_high is a predefined minimum multiplier for supply.

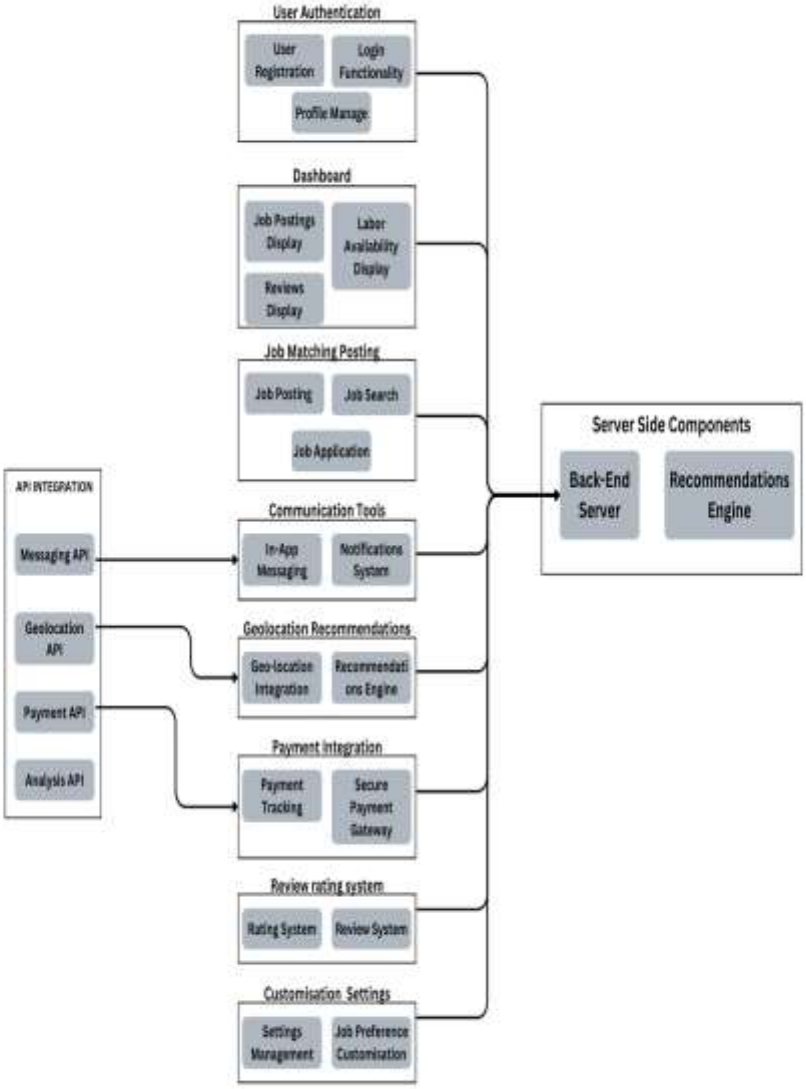

Figure-3 Architecture

5.3 Desired Architecture

6. Conclusion:

The growth of mobile-based applications and other digital platforms has positively changed the agricultural sector in India. Digital tools have also led to social improvements, with many laborers finding better job opportunities and improved living standards by reducing dependency on manual labor and introducing efficiency through technology[20]. It is predicted that 95% of people globally live in areas covered by mobile networks, and it is projected that over 90% of new mobile subscribers by 2021 would come from developing countries. This growth offers an opportunity to integrate rural labor into broader digital economies and could be leveraged for enhancing agricultural output and rural employment [16]. Also, mobile sites, and knowledge-based systems, provide prescriptive advice depending on the crops being grown, the soil status and other geographical information and hence, digital devices in these days in agriculture can hardly be overlooked. Mobile technology has enhanced social cohesion and improved communication among farmers, with 80% of farmers using calls to communicate with other farmers or relatives and 83.63% connecting with retailers [19].

New opportunities open in front of the population living in rural villages due to access to mobile phones, which significantly transforms people's lives. Whereas earlier individuals spent considerable amounts of money, time and effort in searching for employment, citizens of the developed countries are now taking chances, which used to be rare. Temporary work inherent in rural earnings more than farming, gains enormous returns from this liberation from constraints of time and distance. Secondly, mobile technology provides new hope for women-

headed households and those who are peripheral to the core of communities and reveals how innovation can counter an uneven playing field for those who seek employment across the countryside [14].
Finally, assuming there are no drastic changes in the efforts of the policymakers, the agricultural institutions and the technology developers, mobile applications and ICT tools will be a panacea in making the agricultural sector more resilient, more profitable and more inclusive. Realising this vision will not only contribute to the increase of farming household income, but will also facilitate agricultural activity's development in a sustainable and fair manner in the long run.

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