Employee Productivity Modelling on a Work From Home Scenario During the Covid-19 Pandemic: A Case Study Using Classification Trees

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Abstract Employee productivity is recognized as a key factor for the development of any organization. Through many research in the past, "work environment" has emerged as one of the most significant aspects that greatly contributes towards employee productivity. When employees are reverted to a work from home scenario, the work environment can change substantially due to varied reasons such as social, economic and cultural scenarios, different than usual. This research investigates employee productivity in relation to a new work environment that has emerged due to the Covid-19 pandemic. The study aims to find factors impacting on employee productivity under this new work environment and views employees, as subgroups or segments, within the new setup. A survey based on 60 employees of a non-government organization in Sri Lanka, is used to exemplify the approach to meet the study aims. Employee Productivity is considered as a binary variable, the two categories being positive productivity and non-positive productivity, compared to the situation prior to Covid. The classification tree, with an accuracy of over 88%, revealed that, four features, namely, complying with daily hours of work, overall experience of working from home, ease of focusing on work and clear communication regarding work, significantly impacted on productivity. The analysis also showed that among the five different employee subgroups that emerged from the analysis, 36% of the employees forming the largest positive group seemed to be able to comply with the required hours easily, had a good overall experience and were able to focus well at home. On the other hand, 42% belonging to the largest non-positive group stated that their work expectations were communicated but they were not able to comply with the due hours or work per day. The proposed evidence-based quantitative approach has shown promising results in studying employee productivity during a work from home scenario.

Keywords: *classification trees, employee productivity, Covid-19 Pandemic, work-from-home*

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1. Introduction

Literature reveals that employee productivity is closely related to the efficiency of a worker or a group of workers for a given period of time. Among the varied definitions and explanations reported and published in this context, one common highlight is that, employee productivity is key to the success of any organization. Work environment, flexibility, training and motivation, are some important factors that are found to contribute towards employee productivity [1,2]. Successful organizations are cautious about employee productivity and therefore deploy mechanisms to periodically evaluate and take necessary actions accordingly. Periodic staff satisfaction surveys, appraisal forms or informal meetings or communications with the immediate superiors are some common ways practiced to evaluate employee productivity.

For several decades, there had been many researches carried out on employee productivity focusing on various aspects, all over the world. A decade ago, a research focusing on motivation was done by Manzoor & Bahawalpu [3] where the impact of motivation of employees on an organization's success was investigated. They used management theories based on available literature to test their hypotheses. The study concluded that empowerment and recognition play an important role in motivation of employees and such motivated employees contributes best towards the betterment of the organization. On a similar note, Maduka & Okafor [4] investigated how motivation impacts on employee productivity based on a survey conducted across several organizations in Nigeria. Descriptive statistics and hypothesis tests were carried out in their analysis, from which they concluded that motivation was significantly impacting on employee productivity. It was further analyzed to derive that motivation was mainly driving on the remuneration the

employees received in terms of salary, overtime or any other allowance.

Research on employee productivity had been investigated even in the education sector. Hanaysha [5] conducted a research in the field of higher education, based on the direct effects of employee empowerment, teamwork, and employee training on employee productivity. A survey was carried out on employees of public universities of Northern Malaysia, where the analysis was based on 242 employees. Through structural equation modelling, the study showed that all three aspects, empowerment, training and teamwork, had a positive impact on employee productivity of educators.

Duru & Shimawua [6] have conducted a research on investigating if the nature of work environment has an impact on employee productivity. The study was based on a secondary dataset of 200 workers in the field of transport, who were administrative officers and drivers. The method of analysis was mentioned as Chi-squared tests, but details of the structure of the data and how the analysis was used to meet the study objectives were less explained. Their study concluded that, if a good office environment is provided for employees, their morale and their performance are thereby enhanced. Moreover, the study revealed that a good working environment increases individual productivity, thereby improving the growth and productivity of the organization. Taking a different direction, Mohamad Hammoud, & Schrita Osborne [7] conducted a study to explore strategies that some communication business leaders use to engage their employees. The target population was a large organization that has been in the industry for more than a century. It was claimed that, rewards and recognition, empowering employees and building a bond between leaders and employees, emerged as contributing factors for employee engagement in the workplace.

A more recent study was done by Lan Zongjun [8], on factors affecting Employee Productivity in Shanghai. This study mainly focused on three aspects, namely, working environment, welfare measures and rewards and analyzed employee productivity in terms of retention, through a survey carried out in a particular organization. The study was based on a survey done on an area where descriptive analysis was done to explore the variable and a multiple regression model was used to relate the variables. Even though the objective of the study is closely related to the objective of this paper, the model showed low adequacies and may not be suitable to model employee retention. However, the author claims that the study is useful to explore the retention of employees and hence supported exploring employee productivity.

Since the pandemic started in China in December 2019, and soon spread to the entire world within the first quarter of 2020, it has been affecting the day to day lives of many people, due to various reasons such as country lock down, area lock down, restrictions on travel within and between countries, loss of jobs, and even curtailment of usual wages, in certain situations. Physical closure of schools, universities and other higher education institutes, have also made a typical family atmosphere different than usual. Obtaining outside support for domestic work, using daycare facilities, parents having to attend to online learning of children, are some common issues faced by family members, that may be different than usual.

As the pandemic prolonged, a majority of organizations in the world transitioned into remote work mode. Even though this seemed to be the ideal solution at that time, there could be many issues people may encounter with the work from home scenario that may have a direct impact on productivity of employees. It must be emphasized that the home environment and social status of employees vary from person to person, household to household and even among different countries due to various social and economic conditions. Sri Lanka, among many other countries in the world, is different especially with regard to operating family units, mostly living with extended family and living with many generations. A commonly experienced set up is that, many households rely on daily domestic workers for household services. Hence it is important and timely to view and investigate employee productivity of an organization within the new work environment and view the varied segments of employees with regard to productivity and the new environment. The organization will then be able to support the employees to improve their productivity addressing the new set of issues using the best possible strategy, not merely based on their designation but based on their new work environment.

Mahesh & Kumar [9] have researched on the work from home experience of IT professionals, during the pandemic. The study uses descriptive methods and the method of analysis of variance to meet their overall objective. They concluded that the willingness to work from home was based on their dependents at home like parents/partner/children, comfortable space at home, suitable environment at home and good internet connectivity. They stated that, though the technical issues may be handled by the IT professional better than the others, they too encounter other social aspects in the home setup. The study also recommends future research on the work from home scenario on other sectors too. Targeting a similar IT sector, Daniel Russo et al. [10] conducted a longitudinal study through both waves of the pandemic based on 192 software professionals, where many psychological, social, situational, and physiological factors that have previously been associated with well-being or productivity were explored. Some of the key findings of the study were that the quality of social interaction impacts positively on well-being and productivity, while stress, boredom and distraction predicted an individual's well-being negatively. They also state that the same trend was observed consistently across both waves. The research also claims the effectiveness of their approach to study well-being and productivity of software professionals.

This research focusses on modelling employee productivity to explore the impact of various socio-economic variables and work from home environment, and how employee productivity varies across different segments of employees using an evidence-based statistical approach. The targeted employees are from a non-government organization based in Sri Lanka with a range of staff members holding various job descriptions - from support staff, transport staff, administration and finance

staff, project officers and project directors. The services they provide are diverse and strongly depend on the environment that they work in.

The data were collected through a carefully designed survey, that captured certain attributes such as productivity, experience, home environment, the facilities and the additional home commitment that has emerged due to the pandemic. Productivity is viewed by each participant as positive or not, where the impact of other features was incorporated through a modelling approach. A Classification tree under "Decision Tree Data mining" is used to model employee productivity through which the employee structure based on productivity can be clearly investigated. The proposed approach is comparatively easy to interpret and allows the model to be viewed graphically. The method is exemplified using a real-life data set that was generated through a staff-survey conducted in the non-government organization. It is anticipated that, using the proposed approach, an organization can benefit remarkably in extracting the most impacting features on productivity in this new environment, while also understanding different segments of employees with varied productivity ratings, in the new employee work setting.

2. Theory and Methodology

2.1. Survey Design and Implementation

The survey had been carried out soon after the first wave of the pandemic in order to explore the work from home experience. The questionnaire was designed by reviewing information related to the impact of work from home on employee productivity. Focus was also made to incorporate information on the home environment, in the questionnaire to accommodate the home set up. The questionnaire was designed under 4 main subsections: several questioned were designed to capture information under each of the four subsections.

Section A: Employee Details

The questionnaire was anonymized. Only Gender, Age and Employee's work location were therefore captured.

Section B: Home environment

Equipment, Suitable space, Internet connectivity, Access to office services such as email, Teams etc., Ease of joining virtual meetings, and complying with the required hours of work per day were questioned under this section.

Section C: Office arrangement

How easy is it to reach colleagues as and when needed, how frequently an employee interacts with their colleagues, adequate support from direct supervisor, clear office policy, clear instructions regarding work expectations and staying motivated were considered under this subsection.

Section D: Personal life experience

Ease of maintaining focus on work, overall productivity while working from home, compared to being in the office and overall experience of working from home were focused under this section.

Based on the above information, the questionnaire was constructed in three major languages (English, Tamil, Sinhala) using google forms and distributed via an online platform, where the survey link was shared with all staff email group. The survey was designed so that the employees' confidentiality and anonymity were assured. A paper-based option was also available to complement the online survey. The variables covered in the questionnaire are described in Table 1.

2.2. Classification Trees

Classification Trees are used as a modelling approach to classify a categorical feature, based on many predictor variables, and are widely used in various fields of study. Among many other classification models, classification trees are extensively used, mainly due to their ease of interpretation for decision making and ability to exclude features that have no impact on the classifying feature. Moreover, it may also be used to segment the entire data set focusing on the main classification feature. The tree is generated based on recursive partitioning where it splits the data set into smaller groups until a sufficiently homogeneous subgroup is achieved or a stopping rule is imposed. Caution must be taken, however, not to over fit the model.
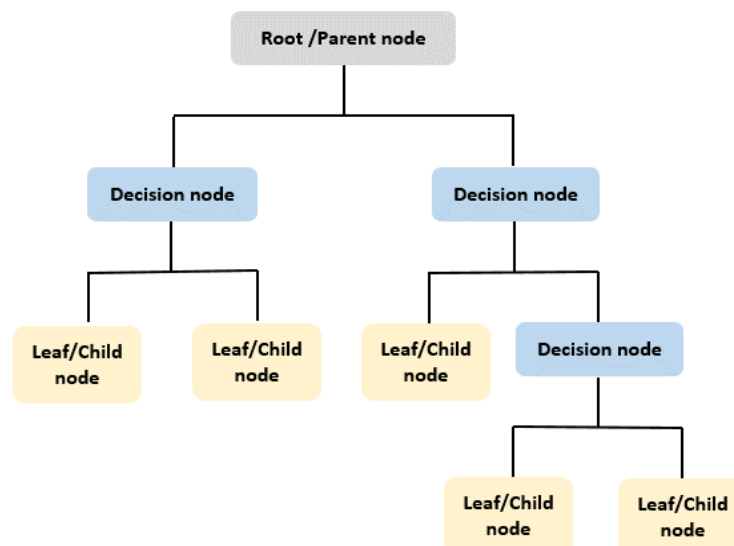

Figure 1. A decision tree diagram

Decision tree classification is described as a supervised learning technique that builds a flowchart, like a tree structure, to partition the dataset based on its features [11]. It consists of a root node, representing the most important feature, branches representing a decision-making rule, and terminal nodes or child nodes representing the outcome of the class [12]. The general structure of a Classification tree is shown in Figure 1.

In this study, a classification tree approach was applied to classify the productivity ratings of the employees with respect to other impacting features and to visualize the subgroups of employees with respect to productivity through a branch of a tree diagram. Recall that this data set consists of mixed types of categorical variables collected on 60 persons. All categorical variables are usually incorporated in the model through dummy variables. To understand and estimate the model performance, the dataset will be split into training and test set to the ratio of 7:3, randomly. That is, 70% of randomly selected data will be used as the training (building the model) and remaining 30% of the data will be used for testing the model for accuracy. A python program was written to prepare the data to suit the analysis and to generate the classification tress.

The approach used the following, to build the classification tree.

- A statistical property called information gain, to select which attribute is to be tested at each node in the tree [13]. Information gain is based on Entropy that measures the extent of impurity or randomness in a dataset.
- GINI index defines the purity of a specific class after splitting along a particular attribute [13]. Closer the Gini index to 0, better the purity of the class.
- Since the dataset is limited to 60 responses, the model was fitted controlling "mini sample split" which is the minimum number of samples to divide internal node and the maximum depth of the tree.
- Thereafter, the confusion matrix was taken, to check for accuracies of the predictions.

2.3. Variables and Data

The data set consists of 60 records obtained on 28 mixed types of variables, including 14 nominal categorical variables, 7 ordinal categorical variables, and a few open-ended variables covering different areas, as explained in Section 2.1, that relate employee productivity with the work from home situation. All relevant variables, except the open-ended questions, were considered in the analysis.

The main feature or the variable of interest considered in this study is the "productivity of working from home", a measurement on a 5-scaled response varying from very low to very high, and the middle being moderate. In this study, as the focus was to see if the productivity is towards the positive or the negative direction in this new work setting, compared to work from office, productivity was re-categorized into two: the positive side of productivity by combining high and very high, whereas the remaining categories, moderate, low and very low formed the other category, non-positive.

Due to the large number of nominal and ordinal types of variables in this data set, each with several answer options, and as this data set is relatively small with 60

employee responses, all variables were re-categorized appropriately for the analysis in order to generate the classification tree with a high accuracy. It is important to note that the analysis and the results are based on the reconstructed factors described in Table 1.

Table 1. Reconstructed Factors and their Measurements Used in the Analysis

Section A: Employee details	
Gender?	Female Male
Age?	Under 30 years/ 30 years 31 – 45 years Over 45 years
Employee's work location?	Colombo District Outside Colombo District Both Colombo and outside Colombo District
Section B: Home environment	
Did you have all the equipment you needed to do your work from home?	Yes No Not applicable
Did you have appropriate space in your home where you could work?	Yes Negative side Not applicable
Was internet connectivity at home a problem?	No Had problems Not applicable
How easy was it for you to access office services (email, Teams etc.)?	Difficult Moderate Easy Not applicable
How easy was it for you to join Teams (or other virtual) meetings?	Difficult Moderate Easy Not applicable
How easy was it for you to comply with 7.5 hours of work while at home?	Difficult Moderate Easy Not applicable
Section C: Office arrangements	
It was easy for me to reach my colleagues as needed	Disagree Neither agree nor disagree Agree
I am happy with how frequently I interacted with my colleagues	
I feel that I got enough support from my direct supervisor	
TAF Sri Lanka's work from home policy was clear	
My work expectations were communicated clearly	
It was easy for me to stay motivated while working from home	
Section D: Overall experience	
How easy was it for you to maintain focus on your work?	Positive Moderate Negative Not applicable
Overall productivity while working from home, compared to being in the office?	Productivity positive Productivity non-positive
Overall experience of working from home?	Positive Moderate Negative

3. Analysis

3.1. Descriptive Analysis

The questionnaire was administered both online and paper-based, where 60 responses were obtained (81% response rate).

Recall that employee productivity was the key variable of interest where it was either positive or non-positive for each employee. Descriptive data analysis was carried out to explore the behavioral patterns of employees during work from home, in relation to employee productivity. Some interesting features related to employee productivity are visualized using multiple bar charts and are described through Figure 2 to Figure 5. These provided some insight into the impacting features related to productivity when considered on their own, but as the features themselves are related to each other, productivity will be modelled using all features, to analyze the impact of every variable on productivity, in the presence of other variables.

Figure 2 visualizes the relationship between the appropriate space available at home and productivity. It can be clearly seen that among those who have appropriate space at home, a higher positive productivity is rated as opposed to those who did not have appropriate space.

Figure 2. Productivity with respect to appropriate space available at home

Focusing on office work from home was considered an important factor for productivity. Figure 3 clearly depicts that there is a relationship between maintaining focus on office work from home, and productivity. As the focus is from positive to negative, the percentage of positive productivity decreases from 73 % to 20% and then to 0%, clearly indicating the impact of focus on productivity.
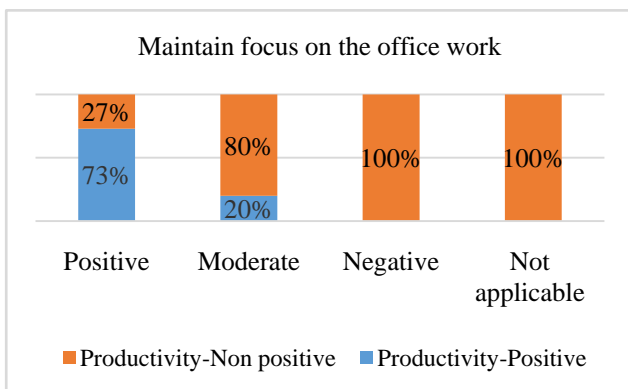

Figure 3. Productivity with respect to ease of focusing on work

Overall experience of working from home with respect to productivity is described through Figure 4. The highest percentage (74%) for positive productivity is observed when the experience is positive. It is interesting to note that the positive productivity percentage is higher among those who had a negative experience as opposed to those who reported the experience as moderate. The possible reason is that experience on its own may not clearly explain the productivity variation but rather may explain productivity combined with one or more other variables. It is noted, however, that the highest positive productive percentage was observed among those who were positive about the overall experience.
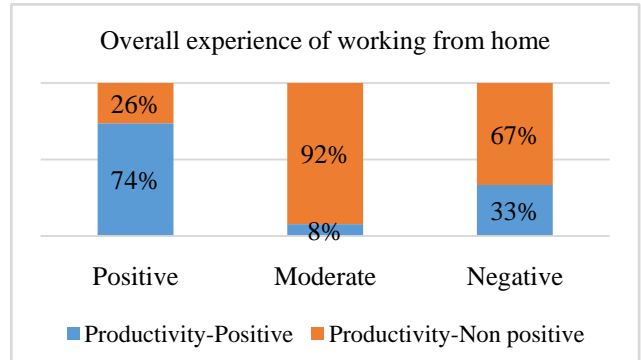

Figure 4. Productivity with respect to overall experience

Motivation when physically being in office can be very different when working from home. Figure 5 describes the relationship between productivity and motivation.
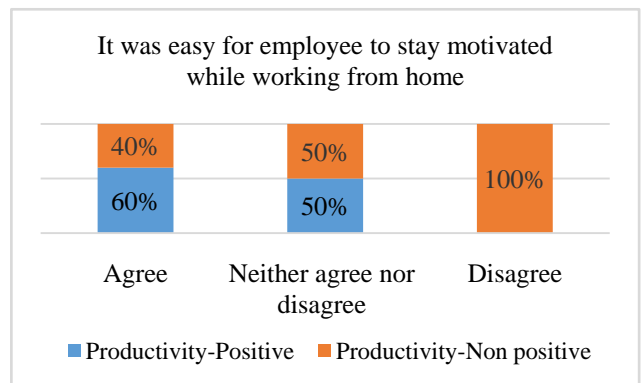

Figure 5. Productivity with respect to staying motivated

It appears that the positive productivity percentage is the highest among those who agree they were motivated, but that percentage was marginally different from those who were moderate about motivation. Among those who were not motivated, however, everyone was non-positive about productivity.

3.2. Implementing the Classification Plot

To justify the associations between productivity and the other variables statistically, a classification tree was implemented.

The classification tree depicted four important features impacting on the overall productivity while working from home, and the questions relating to those features are listed below.

- How easy was it for you to comply with 7.5 hours of work while at home?
- How would you rate your overall experience of working from home?
- How easy was it for you to maintain focus on your work?

- Employee's work expectations were communicated clearly

The output of the generated classification tree and is shown in Figure 6.

It can be seen that the intensity of the color changes with the GINI value in this output. As the GINI value drops the intensity of the color increases. The shades of orange represent the productivity non-positive group whereas shades of blue represent the productivity positive group. As an example considering the root node, the first line shows the condition, secondly the GINI index, thirdly, size of the sample and value is depicted as a number of non-positive responses on the left and positive responses on the right. Finally, it shows the output target variable.
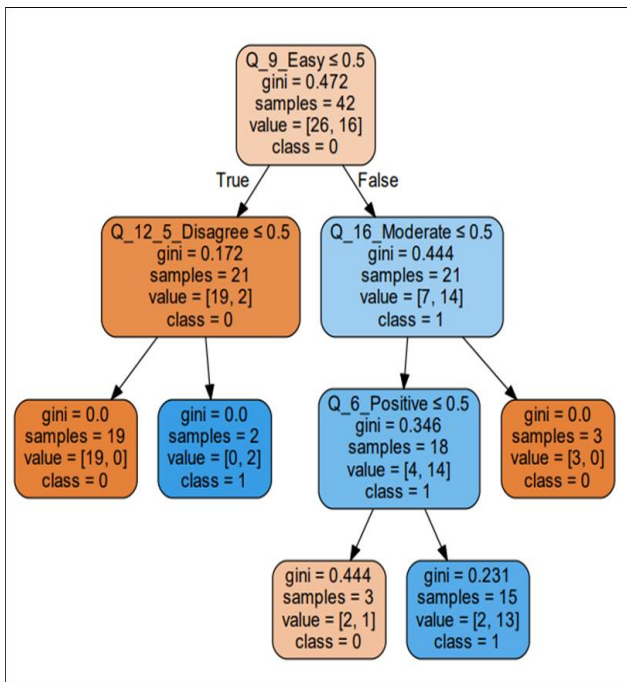

Figure 6. Classification tree generated through the python program

Based on the above classification tree, the following diagram, is created by the authors to visualize the classification of productivity clearly, based on the four significant factors.

3.2.1. Interpretation of the Classification Tree

Recall that the classification tree is generated on 70% of the data, i.e., based on 42 randomly chosen employees. The colour blue indicates positive productivity whereas the colour orange represents non-positive productivity. The intensities of colour indicates the purity of the class; higher the purity, the more intense the respective colour.

The interpretation of Figure 7 is as follows – Those who could comply with the required hours.

a) The root node of the tree which is the most impacting factor for productivity appeared to be *ease of complying with the required number of working hours for the day*, by an employee. Accordingly, this node shows class 0 since the majority belongs to the non-positive productivity category.

b) Those who were more likely to comply with the required working hours were impacted by their overall experience of working from home. Those who reported moderate experience were all non-positive on productivity while working from home. This formed one group of employees who were non-positive on productivity. The class is 0 and the Gini Index is 0.0 indicating the purity of split.

c) On the other hand, the employees reporting either negative or positive concerning the overall experience were impacted by whether they can focus on work from home or not. The majority of those who could focus, were positive on productivity and is indicated by Class 1 and colour blue. This formed a positive productivity group of employees. The others who were not able to maintain focus well from home, formed another non-positive productivity group of employees.
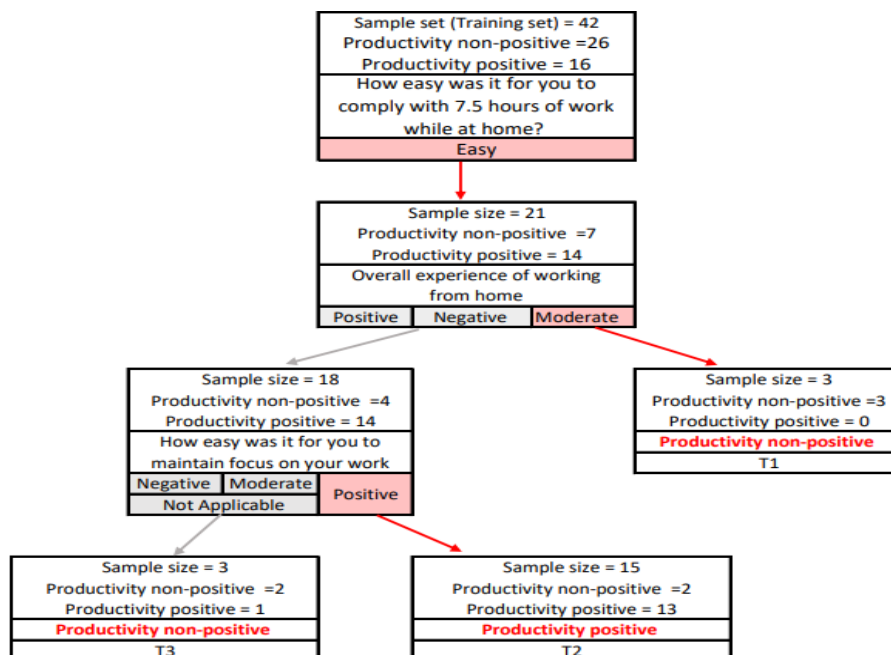

Figure 7. Interpretation of the classification tree – Branch (Easy to comply with required office hours per day – the right hand side branch of Figure 6)
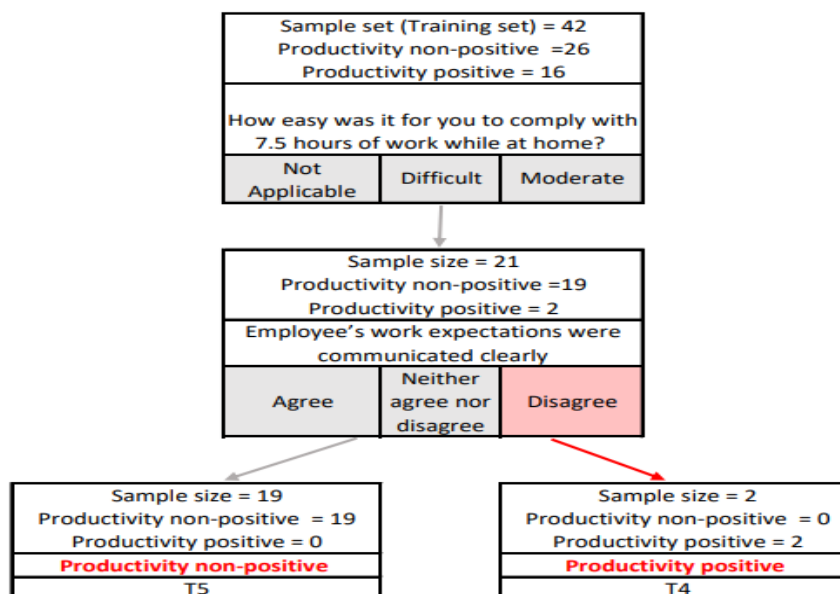
Figure 8. Interpretation of the classification tree – Branch (Not easy to comply with required office hours per day – The left hand side branch of Figure 6)

The interpretation of Figure 8 is as follows – Those who could not comply with the required hours

a) Employees who did not comply with working the required number of hours per day were impacted by whether their work expectations were communicated clearly to them. The majority of them were those inclined to be non-positive with regard to productivity.

b) Among those who said the communications from office regarding work were clear, a majority seemed to be non-positive towards productivity and forms another non-positive group. There was also a small group who said the communications were not clear but have indicated productivity as positive, forming another group of employees.

Accordingly, five different subgroups of employees, based on productivity, were identified through the classification tree.

4. Discussion

Employee Productivity has been identified as one of the key aspects that contributes towards organizational success. As such, research has been done focusing on various directions, sectors and have used many qualitative and quantitative methodologies to meet them. Employee productivity is the quality of the employee providing his or her services within a stipulated period of time for a day and depends on facilities such as training and guidance provided to the employee, remuneration and promotions, motivation, to name a few. Much of these facilities are confined to the office setup and can substantially change under the "work from home" setup.

There has been a total change in the working environment of many employees all around the world owing to the pandemic. Working environment, for most employees, has become their own homes where the home set up can vary substantially due to various reasons such as social class, economic status and family responsibilities. In Sri Lanka, family units operate mostly with either extended family members living in the same household or parents living in the same household taking care of children, or both. Due to the pandemic, many challenges are also faced by households with regard to the availability of domestic support and day care facilities, internet connectivity, workspace, and many more. When the work environment reverts from office to home, in many situations, there could be more than one person from a single household, working from home. Moreover, in the same household, there could be others learning online from home. This calls for high internet bandwidth that affects the financial expenditure more than usual. There could also be no proper workspace or there may not be sufficient space to be shared with others who are also working from home. Very often, working from home requires a level of multi-tasking that the regular office space does not, and could possibly affect women than men, in a household. People will have to get involved in home matters even during office hours, perhaps due to young child being around or elderly parents not having domestic help as usual. As such the home set up for office work may not provide the ideal environment for everyone, and thus may adversely affect employee productivity. Moreover, working women, will encounter a new set of household issues to cope with, and possible have an impact on employee productivity.

This study analyzed survey data of 60 employees of an organization, aiming to identify features of the home set up that affect employee productivity. The organization is a non-government organization, and therefore the job descriptions of its employees varies from office and transportation support staff to administrative staff and then to project leaders. Due to their job description, some may not be able to work home whereas some may prefer working from home. Therefore, it was also important to view the employees as subgroups, based on employee productivity. It was anticipated that the survey results will guide the top management of the organization, to take necessary actions based on the findings that are related to the new working environment.

The four features that emerged as important, in relation to productivity were; the ease of complying with 7.5 hours

of work while at home, the employees view on overall experience of working from home, maintaining focus on work from home and finally whether the work expectations were communicated clearly. Based on varied options with regard to these four features, the employees of this organization were subgrouped into five groups. Two groups emerged to be positive towards productivity while three groups were non positive towards productivity. The classification tree analysis provides an accuracy of 88% justifying the features impacting on productivity and the criterion for subgroups of employees.

These groups are described in relation to the four features impacting on employee productivity. Recall that the productivity was originally a 5-scaled response variable where the positive productivity category was defined by combining high and very high options, whereas the rest very low, low and moderate, formed the non-positive option.

- If an employee can comply with the required number of hours per day and have either a negative or a positive overall experience, and who can focus on work from home, then an employee is more likely to be positive with productivity.
- If an employee can comply with the required number of hours per day and have either a negative or a positive overall experience, and who cannot focus on work from home, then an employee is more likely to be non-positive with productivity.
- If an employee can comply with the required number of hours per day and have a moderate overall experience, then an employee is more likely to be non-positive with productivity.
- If an employee cannot comply with the required number of hours per day and have been communicated on the expected work, then an employee is more likely to be non-positive with productivity.
- If an employee cannot comply with the required number of hours per day and have not been communicated on the expected work, then an employee is more likely to be positive with productivity.

When studying the five groups it can be clearly seen that a single feature does not separate employees as productive or non-productive but rather five different combinations from the four features signifies the groups. It is with noting that, although it was anticipated that gender may be a significant feature with regard to productivity, the classification tree described in this analysis did not find gender as an impacting feature. Recall that the classification tree was generated controlling for a maximum depth and a minimum split sample size due to the study sample size. However, relaxing the above controls are possible with larger study groups, which may have generated more significant features impacting on productivity.

Even though this cohort is relatively small, five different groups emerged from the study. Recall that services of most of the finance, administrative and support staff are confined to the office environment, where physical access to the office premises are required. On the other hand, the project related staff are able to remotely work, with the minimum need of access to office environment. It is therefore anticipated that this variation must be due to the different employee categories that are in this organization, with their services being very different, and perhaps redundant in a work from home situation.

It must be noted that, even though the classification tree provided a promising result with high accuracy, it is usually recommended to be used for larger samples to achieve high accuracies. However, the application is novel to this area and illustrates the strengths of using such an approach in analyzing a scenario of this nature.

5. Conclusion

This research highlights the importance of investigating employee productivity in terms of the work from home scenario and suggests an effective evidence-based approach to explore factors impacting on employee productivity under this new setup. Through this case study, it is concluded that employee productivity is significantly impacted by four factors, namely, ease of complying with the required working hours, overall experience on working from home, whether clear instructions were given on the work expected and whether employees could focus on their work, from home, in relation to this organization. Moreover, the employees of the organization were segmented into five groups, with respect to productivity, two groups were positive on productivity and three were non positive. This enables the organizational top management to address the issues related to productivity of these subgroups, more efficiently. Although employee productivity has been explored based on several factors, by many researchers, using a wide range of methodologies, the use of classification trees to model employee productivity has not been commonly reported or highlighted. Moreover, using the segmentation emerging from the analysis to understand the different employee categories related to productivity, is evidently useful to analyse employee productivity. It can also be emphasized that the classification tree approach is not confined to be used when researching on employee productivity but can also be appropriately implemented to investigate and visualize any other social phenomenon of this nature to provide evidence-based results.

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