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RESEARCH ARTICLE

An Industrial Investigation of Human Factors Effect on Software Productivity: Analyzed by SEM Model

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***Abstract:** The software productivity in any software organization can be greatly enhanced if the human factors associated with the company employees are aligned in proper direction of cooperation and unity, among different developments teams working on same software project. In brief, the growth of any software company highly depends on understanding the concept of software productivity, and a means to measure and quantify it. In the present paper we will analyze some critical factors associated with the software development productivity, using the industrial case study data gathered after conducting questionnaire, interviews, etc. in a typical medium sized software firm. The data analysis is done through the Structure equation modeling approach. Next we present the effect of human factors on software development productivity. It's important to combine both the Human factors and software productivity, in our study so as to arrive at one final conclusion about factors affecting the software development productivity. Finally the paper ends by having discussion in brief about the results, and future work scope about this topic.*

***Keywords:** SEM - Structure Equation Model, SASE- Social Aspects of Software Engineering*

1 Introduction

Generally speaking, the term "software development productivity" has multiple ways to be analyzed in any software company, for the benefit of its product and maintaining good competitive advantage over its competitors. The process of software development involves human effort which includes considerable team work and cooperation [11].

Now days the topic of human factors has become an important investigation area by industrialists and researchers. And hence, one can conclude from it that the success of any software product depends greatly on how social factors play role in respective software company or organization. The communication skills in software team should be managed and coordinated in such way so as to attain the desired results, satisfying the needs of team and individual.

In our study the focus is made on analyzing multiple human factors affecting the software productivity. In the past, numerous works had been done on studying the human factors [13], but very few papers/work are available on studying the effect of such factors on software development productivity. In our present research work we developed the relationship between the two factors mentioned above i.e. human factors and productivity, and then developed a new term "human productivity of software process". This term "Human productivity" will constitute productivity issues related to the social structure of software organization.

1.1 Research Objective

The initial focus of research is made on determining the dynamic relationship between the human productivity and software productivity based on the available literature database, and then directing our case study in that direction, for a typical software organization.

In order to analyze the results obtained through the industrial case study, we used Structure Equation Modeling (SEM) approach to check the correlation between two variables i.e. human productivity and software productivity.

On the one side there are different factors affecting the software productivity directly, while on the other hand several factors affecting the human aspect of software productivity can also be found in literature database.

In past, not so much work had been done on analyzing the human factors affecting the software development productivity, especially through the use of SEM. Therefore, this paper presents one of the early attempts to use SEM technique, to determine correlation between human productivity and software productivity in a typical software organization.

In the coming sections, several definitions related to human aspects in software organization are introduced and analyzed in the light of available literature database. Then we define models and present some important results obtained from our case study to prove our approach. Lastly the paper concludes with the results and discussion section, and scope for future work.

2 Human Dynamics

Human dynamics is an important branch of modern day science, specialized in analyzing/studying the socio-economic aspects and human factors of our society and their interaction with each other. It is possible to understand the important concepts of the Social Aspects of Software Engineering (SASE) [13] using the definitions covered by the Human Dynamics zone. Now, it is possible to understand the human dynamics concept in the light of SASE. This would help in software organization to facilitate the mutual understanding between different software teams working on project, and also within organization.

2.1 Productivity

The manufacturing of any Software involves the capital, through which the desired outputs are produced at the expense of specified input/inputs depending on availability of resources. Thus, measuring the software productivity becomes very important factor in understanding this economic process of converting inputs/input to output/outputs in software organizations. One can conclude from the above statement that the effectiveness of any production process depends on its productivity.

One of the widely used definition of "software development productivity" available in literature is that "It is the ratio between the inputs (e.g. the cost of work/resources) and the outputs (i.e. software output or services) within the production process of software development [7]. Generally, in many cases software size is one of important measure for software productivity [25]. Presently, there are different ways to measure software size, among these one of the most important metrics is by lines of code. Also it is one of the common measure for complexity of software [18]. However, other measures for measuring software productivity include function points per hour [21], which is associated more with the user functionality of software, effort measurement [6], etc. Practically speaking, as suggested by [23], it is quite difficult to find one particular way for calculating software productivity [16]. As suggested by Scacchi [22]

there is need of multi-dimensional analysis of productivity because several times in software production process, multiple outputs are produced at same time.

The members of social network expect some profit and gain, while working collectively for one organization in one group. But this gain or profit is not so easy to achieve, and it depends on the level of networking and social connections they have [8]. One of the methods to exchange goods [15] is the social behavior for them. Also they should share the knowledge with each other, so that they can transfer this knowledge to their future generations, which would help in growth and well fare of the society. Bourdieu stated that the term sociality is affected by the knowledge available and structure of human thinking [5]. The productivity main focus is related to economic growth and progress, but, it has also very important social aspect which was referred by Barnett. The productivity effect on economy is definitely one of the most important area that researchers focus on, but also sociological concept of productivity is very important for today's organization firms and companies [2]. From the economic point of view, interests of people working in group are directed, developed from the certain factors like individual trust, networks influence, etc. [9]

In short the term "Productivity" is not single dimension. It is affected by different factors like working conditions, communication skills between different members of team, workforce quality in Software Company, etc. It is difficult to identify all the human factors associated with software productivity, e.g. management capabilities, communication skills, etc. It was stated by Abdel-Hamit[13] that if each member in team utilizes his or her maximum potential to carry out his/her assigned task, then maximum productivity of final product can be achieved. Two common factors as per Abdel-Hamit [13] study associated with poor productivity and quality issues were (i) team resources and (ii) task characteristics (nature of tasks). It was reported that due to the above two factors, motivation level and communication cost was affected in software development process.

2.2 Human Productivity

In terms of economic growth of software industry, it is quite important to continuously increase the productivity of company employees and organization. There is need to focus on human factors, associated with software development productivity. In the literature multiple human factors affecting the productivity can be found such as communication, interaction, trust, etc. Understanding the effect of each of these human factors in a software development task is a very important branch of productivity. Therefore, human productivity is directly linked to the software productivity. Higher the human potential or human productivity, larger will be the software productivity.

The human productivity is the result of human interactions in the neighborhood and company. The quantification of "human productivity" term can be useful to understand the mathematical correlation between software development productivity and human productivity. Basically, human productivity highlights the importance of all social factors in a software organization. The number and type of such human factors may vary from small sized to large sized software company, depending upon the type of Software Company.

3 Modeling Strategies

Now we must focus on the important factors affecting the human productivity, which in turn can affect the software productivity of an organization. Here we will discuss about the models and investigation methods associated with human productivity factors. To begin with, we apply the structural equation modeling to our industrial case study data collected, on which we build our productivity model. Secondly, we highlight the importance of human factors affecting human productivity and then obtain the correlation between different factors of productivity. Finally the results obtained from the productivity model are analyzed and discussed to reach at some conclusion.

3.1 Work Methodology

In this section, we will discuss about our basic strategy developed to find the correlation between the human productivity and productivity (refer to Fig. 1). To start with, we already know from the literature review that human productivity is correlated with productivity. Therefore, after exhaustive literature review from available resources, we tried to find out some critical factors affecting the productivity, as indicated in Fig.1 in our next step.

Although, in the literature database there are many such factors affecting productivity, but we focused only on some important one. After selecting the factors (to be taken into consideration in our analyses), we refine our search by consulting the company personals, to get their opinion about these factors in the next step. Based on the ideas and opinion of the software organization employees, we made few changes in our initial settings. Next step was to develop survey instrument for analyzing the data obtained from different factors selected in previous step, so as to refine SEM. Finally, the positive correlation was obtained between the human productivity and productivity as shown in Fig.1 (last step).

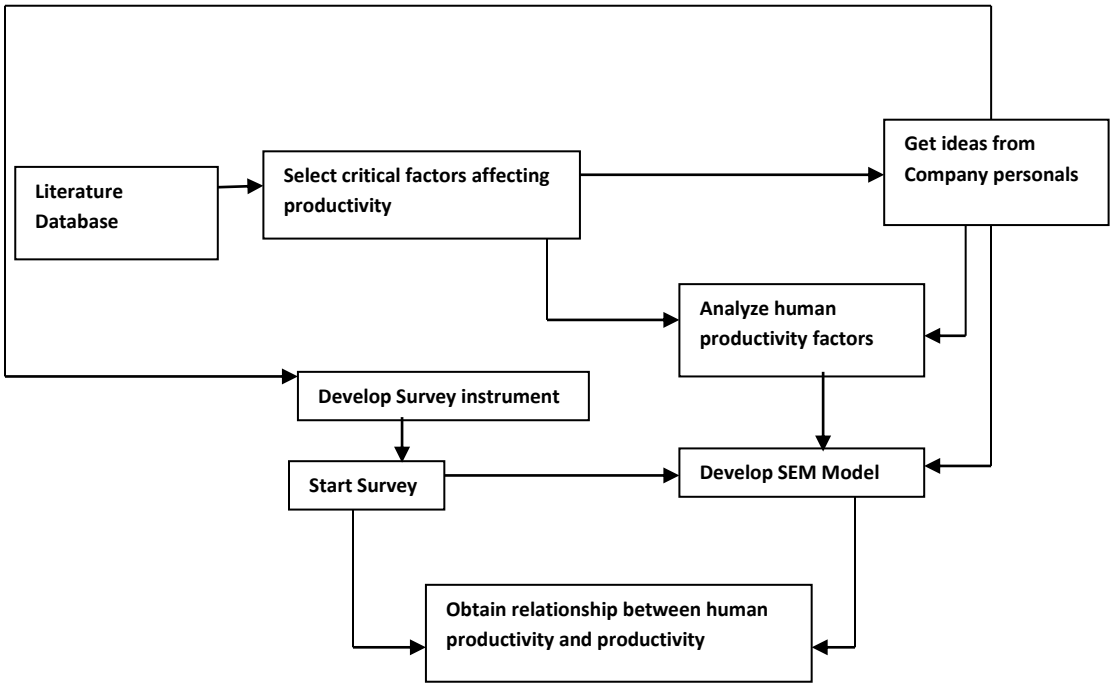

Fig.1 Software productivity analyses approach (starting from scratch to final result)

3.2 Structural Equation Modeling

Structural equation modeling, SEM [14] consists of analyzing the variables and empirical data using flexible statistical techniques (i.e. factor analysis, multivariate, multiple regression analysis,). Variables are usually of two types i.e. observed and hidden (latent). To obtain the correlation and structural relationship between these, we use the multivariate (multi equation) analysis technique in SEM [20].

Generally speaking, in SEM models, the observed and hidden variables are connected to each other through a set of equations, which needs to be solved using the SEM techniques. These equations are often developed and applied in fields of econometric methods [1], sociology [4] and psychology [3]

3.3 The Model analyses

In our analysis the main variables of productivity and human productivity are of latent nature, and hence they were the important variables in our SEM technique. In past, there is not so much work done to find the relationship or correlation between the productivity and human productivity of software organization.

However, through the literature review and conducting company personal interview, we choose most important factors for measuring the productivity as (i) Technology, (ii) Working culture, (iii) Interest in individual Job, (iv) Complexity, and (v) Team Size. For analyzing the human productivity we chose four widely used observed variables (i) Manager skills, (ii) Team Unity, (iii) Social Life and (iv) Meetings frequency. By the application of qualitative and quantitative methods, it's not an easy task to obtain complete data about the productivity affecting factors.

The creation of new people groups is one of the efficient ways to get that information [19]. The advantage of group creation is that the people can discuss and share their past experiences, and form new innovative ideas based on group member's opinion [24]. Through the literature review, the factors affecting both the human productivity and productivity were chosen and then given to focus group (of company employees) for analyses and study.

The group session was started with an introduction speech to raise the morale of participants about the topic and its importance as mentioned by Krueger [19]. One person was assigned the task of writing notes, while we started asking company's management team about the productivity related factors importance.

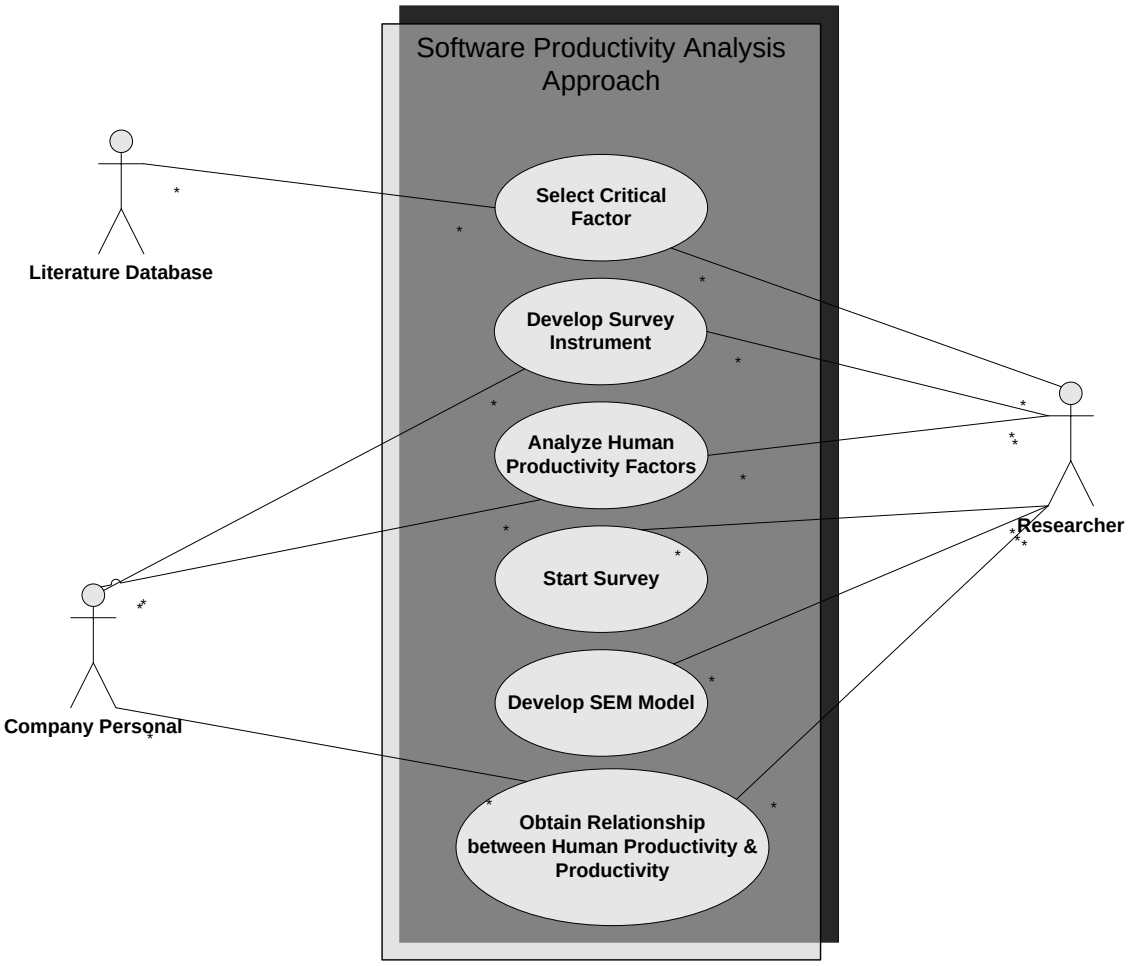

Fig.1.1 USE CASE Diagram- Software Productivity Analyses Approach

A Handbook containing few questions about productivity was given to each of the participant. The questions were as follows:
(1) How do you define productivity in software teams?, (2) Which factors affect the software productivity most in your opinion , (3) Among the factors mentioned in answer of Ques. 2, which is the most important factor , (4)
What do you know about human factors of productivity and (5) could you name few of the important human factors affecting the productivity?
It was observed that participants took interest in the topic and discussed the human factors associated with productivity and their impacts also e.g. task rotation, the communication frequency and team augmentation. After the discussion we came to know about the industrial management team view of software productivity and factors affecting it. We compared the results with the literature we had, and tried to found out the difference between practical (industry) opinion and literature review ideas. After obtaining this information through group discussion, we refined list of factors obtained previously from literature review database.
The results obtained from the group discussion also helped us in designing survey instrument to measure the effect of both productivity and human productivity.

3.4 Structural Equation Modeling for Software Productivity
At the present, there is not any approved model for measuring productivity [16]. Therefore, it's possible to consider the human productivity and productivity as hidden variables in our research paper. Not only this, but they both had strong positive correlation also.
As mentioned in previous sections, after careful selection of observed variables (effecting the human productivity and productivity) from literature and refining it after group discussion, we set the human productivity model by applying the SEM technique as indicated in Fig 2.The circular boxes represent observed variables in our problem while rectangular boxes indicate the hidden variables. The effect of each factor can be observed by lines connecting different circular and rectangular boxes in Fig.2

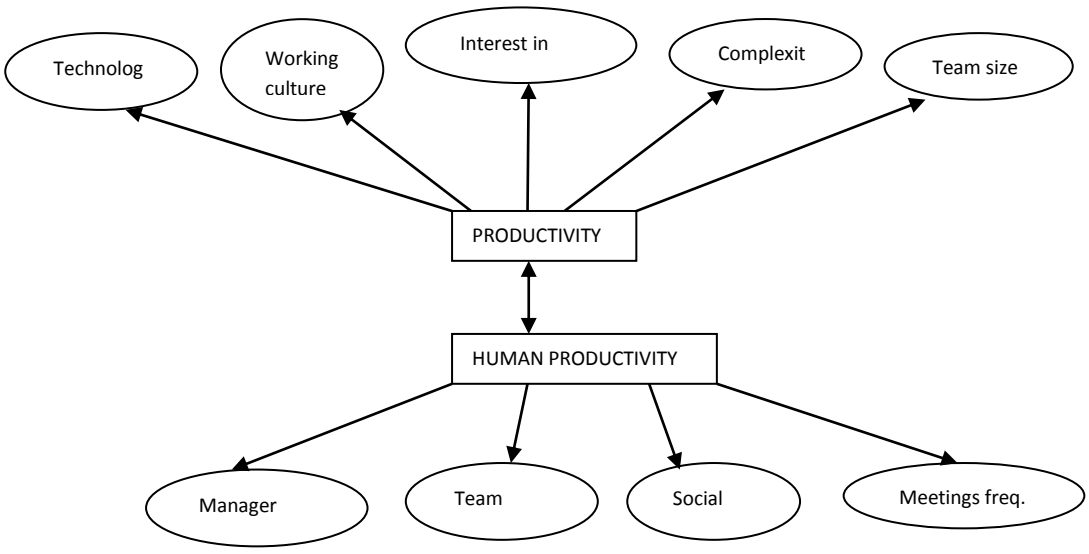

Fig.2 Human Productivity Model

The entire modeling using the SEM technique was done in well-known LISREL[17] software, widely used in different industries for Structure equation modeling. As can be observed from Fig.2 there are total nine observed variables and two hidden variables. All observed variables are related to either of two latent variables, and the productivity and human productivity are bivariate correlated.

Total of 200 participants were involved in analysis. Our first step was to begin the analyses with testing the measurement model and then next step involved the structural model. For the calculation of model parameters we applied on the collected data maximum-likelihood method. It was observed that case of null hypothesis, in which the variables are uncorrelated (i.e. poor scenario) was negligible when λ^2 (93, N = 200) =2105.15, p<0.001

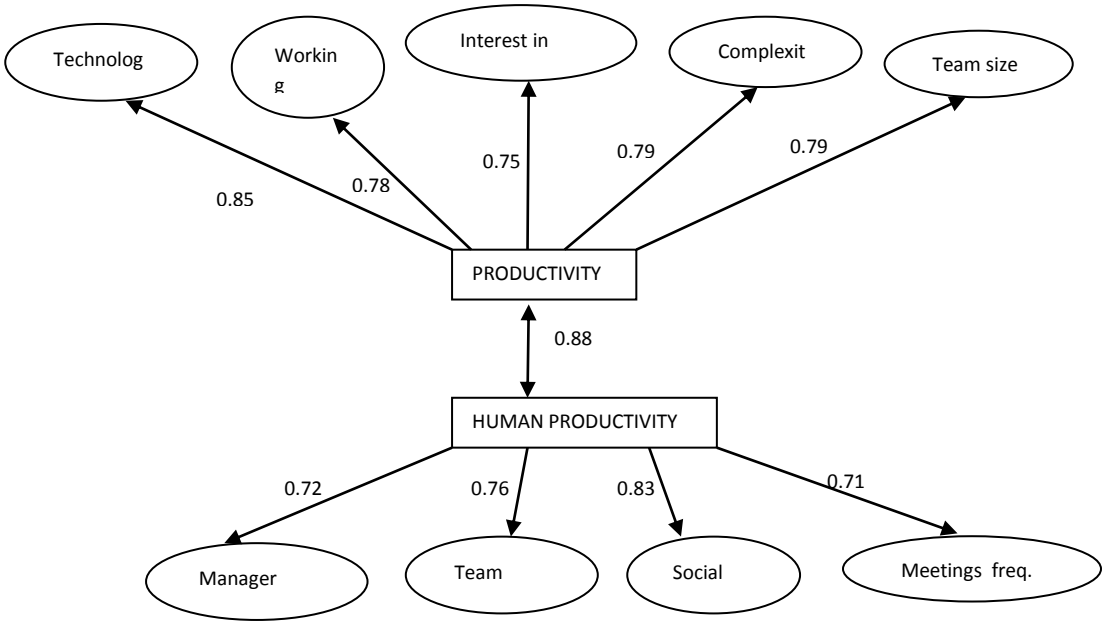

Fig.3 Results of applying the SEM approach on hypothetical Human Productivity model.

The good data fit was observed for our hypothetical model l (see Fig. 2), for the case λ^2 (80, N = 200) = 3899.15, p < .001, where RMSEA = .079, GFI = .95, AGFI = .89, CFI = .97, NFI = .97. The structural correlation was quite strong and good between the hidden variables at p<0.05. The highest factor value was associated with "Technology" (Factor value = 0.85, p<0.05). Therefore one can say that "Technology" affects the productivity most. While, the Human productivity is influenced most by "Social Life" (Factor value = 0.83, p<0.05)

4 Conclusions and Future Work

Our main effort in this paper was to develop an empirical productivity model showing the relationship between the two hidden variables i.e. software productivity and human productivity.

The results obtained and data gathered were discussed with management teams and group members (participating in our study work) of a software organization. To start with, the survey questionnaire was prepared and distributed among 200 participants from different background and software development teams. The data collected from their answer about different questions related to human productivity and productivity was gathered and analyzed. Then, it was possible to build our structural model based on nine of the most critical factors affecting the productivity and human productivity. The structural model was solved using the SEM technique in LISREL software.

Solving the structural equation model network, gave us the correlation between human productivity and productivity terms, and also the effect of each of the nine critical factors on either human productivity or productivity.

In the past not so much study had been done on using the Structural equation modeling for the productivity calculation. However, Foulds et al. [12] used the SEM for measuring the productivity of information system. Foulds in his research work gathered data from participants working in different information technology organizations. Then applied this data to Structural equation modeling to test and analyze the productivity framework for big IT firms. The results of the Foulds study indicated that good software productivity can be achieved by better dynamic approach to project management.

Our research paper is quite useful in the field of software engineering. Since, it deals with one of the important aspects of software engineering i.e. software productivity. Also we developed the relationship between the software productivity (of any software company), and human productivity (i.e. human factors). Now, this correlation (between software productivity and human productivity) is quite useful in practical situations, because most of the software development tasks are assigned to different teams inside organization. And each team constitutes different members. Studying the nature, behavior of each team member becomes a vital factor, in order to enhance the team member productivity, which will in turn enhance the software development productivity also. Also, by applying the SEM technique on the empirical data gathered from sources, the relationship between productivity, human productivity and factors affecting each of these variables were studied. Therefore, from practical view point, the company's management team should focus on controlling the critical factors (like technology, social life, etc.) so as to increase the software development productivity. Next, we introduced concept of human productivity, which had not been studied in detail so far by researchers. Therefore, this paper could present good and new ideas about human productivity and factors affecting it. By getting the insight into different productivity terms, one can find the ways to enhance software development productivity. Also, our approach can be applied for not only just for a medium sized software company, but also on small and big software companies, so as to observe the effect of size of software company on productivity related factors. This could help us in deriving at some conclusion about different productivity factors and their relation with sizes of Software Company.

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