Analyse Agile Software Development Teamwork Productivity using Qualitative System Dynamics Approach

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***Abstract*—A highly productive team throughout an agile software development process is very instrumental in achieving project success. This research presents a system dynamics (SD) based approach to model agile software development teamwork productivity by analyzing productivity influence factors. Identification of main factors influencing productivity and how they impact agile teamwork are carried out through interviews, survey and literature review. A study has been conducted on seventeen software companies in Bangladesh. From the perspective of agile team members, the four most perceived factors impacting on their productivity are team effectiveness, team management, motivation and customer satisfaction. Lack of management support is found to be the most mentioned reason for failed agile project. The findings from these sources are compiled into a Causal Loop Diagram (CLD) for qualitative analysis of the teamwork productivity influencing factors. The resulting qualitative model is expected to provide more insight into the agile teamwork dynamics and establish a basis for a further quantitative modelling. Using the proposed model, the project manager may find the origin of a decrease in productivity, evaluate management strategies along with their effects on teamwork productivity. The future step will be the dynamic simulation of the teamwork productivity model based on the qualitative model in this paper.**

Keywords-agile teamwork productivity; influence factors; qualitative system dynamics; team effectiveness.

I. INTRODUCTION

The objective of any software company is to be efficient and achieve maximum team productivity by being cost effective and reducing development time. A highly productive team is the most important factor in achieving project success at different stages of an agile software development. For efficient management and a better control over the agile project team, it is important to understand the team dynamics and effects related to agile practices that influence the development team's productivity.

Research has been largely carried out to identify factors that contribute and influence productivity in traditional software development. There are four main factors generally discussed [1]: the product being developed (characterization of the specific software), people (team members, capabilities, experience, motivation), project (management and resourcing) and processes (tools and software methods). However, agile teamwork productivity is a function of various controllable and uncontrollable factors [2]. The relationships between some of these factors and productivity may change under new software engineering practice and culture [3]. The factors change over time as expectations change. The software industry is also different from country to country as are the resource availability, the laws which govern it and the developer's cost [4]. In addition, actual productivity measurement becomes more difficult when agile software developers perform knowledge-related tasks (e.g., creating, storing, sorting, retrieving, applying and acquiring knowledge) where the product is usually intangible, rarely has single way of doing it, and it is difficult to quantify [2]. Since knowledge is complex and hard to evaluate, it is difficult to interpret the productivity of the agile team member's simply by source line of code (SLOC) or function points produced per unit of time/cost [3].

Despite the increasing acceptance of the agile methods, insufficient research has been empirical on the effect of software development productivity [5]. A better knowledge of the factors and the mediators that influence agile teamwork productivity could help determine where management efforts would be focused to improve productivity. Agile team members also should learn to interpret and manage productivity factors regularly as they are self-managed. The researchers have highlighted the value of team learning to help organization achieving team effectiveness, better ways to solve problem and increased productivity.

Since the agile project team is the most dynamic element in the software development sector, improving team productivity has become a target for software companies in everywhere. The aim of this study is to analyse and understand the complex interdependences and underlying structures at the team's perception level, which influence agile teamwork productivity over time. This paper determines the major factors impacting teamwork productivity in Bangladeshi software companies through a survey and interviews that have been conducted with agile teams to rank the most influential ones among them. The major factors are to be modelled using a qualitative SD approach. This conceptual model will be used to examine the internal dynamics existed within the team and the

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organizational resources that are used to support them. The future contribution of this research shall provide a strategic (quantitative) model that tells the project manager in advance about the degree of impact these factors will have on teamwork and may identify the origin of a decrease in productivity. Therefore, the agile teamwork productivity may be improved by implementation of management strategies. The scope of this empirical findings considers the Bangladeshi software companies as a case study, which can in turn make the research results beneficial to these companies. However, it is thought that other countries will follow a similar affect to those identified here and its results could be generalized by following the proposed model.

The remainder of this paper is organized as follows. Section II includes a literature review, section III presents the research method and design. Section IV describes the survey results and Section V explores the structure of the qualitative SD model. Section VI describes some limitations of this work. Finally, Section VII describes the conclusion and future work.

II. LITERATURE REVIEW

There are several studies that attempted to assess the impact of some of the influencing factors on agile teamwork productivity. Only Melo et.al [2] analysed the major factors influencing agile teamwork productivity using the team's perception as one potential dimension to understand their overall productivity. Through perceptions, they found that team management is the most influencing factor on agile team productivity. SD technique has been applied in software engineering fields for modelling purposes, which is important for the organization and the project. There are few researches [6][7][8] that attempted to evaluate the impact of some of the influencing factors on productivity separately using SD. However, the complex inter-related structure of all the major factors effecting the teamwork productivity was not considered by the previous works. Abdel-Ahmed [7] investigated the effect of various management policies on development cycle time, quality and effort. His works however adopt the waterfall method which limits their applicability in recent software project and more importantly, does not focus on the agile principles.

In addition, evaluation of individual productivity may not affect the productivity of other team members [9]. These ideas provide a motivation to study teams' productivity, not individuals. A number of studies exist on teamwork in agile software development on a range of topics relevant to composition of team [10], task-effective norms in teams [11], team member's motivation [12], and the importance of a team vision. Yet others have focused on team's communication [10], decision making [13] and self-management [10].

Another stream of research has focused on team performance in agile software development to analyse the teamwork. Team performance refers to evaluation of the results of the teamwork. Moe et al. used two team performance models to explain teamwork in a project adopting Scrum: The Salas et al. model [14] and the Dickenson McIntyre model [15]. Melo et al. used the 'Input Process Output' model to identify team productivity factors in a multiple case studies. Dingsoyr et al. [16] described agile software development as a sociotechnical system comprised of human (socio) and technical entities. Technological interventions do not increase sociotechnical system effectiveness if they are not supported by social (self-managing team and group) components of the system. Such team interactions are one of the important parts in software development. Thus, recent focus on agile software development has increased interest in analysing self-managing agile teams and how to effectively make team productive [16]. Boehm [17] reported in his productivity estimation model, Constructive Cost Model (COCOMO), that productivity of a software development project is mostly affected by the development team and their team management. Scacchi [18] also identified that poorly managed or organized project's productivity was mostly lower than those projects which were well managed. Throughout the literature review, it has been observed that there is a lack of well-established dynamic theory about agile teamwork. This study seeks to fill this gap by developing an integrated model, which represents the inter-related structure of productivity influence factors and how they impact (positively or negatively) agile teamwork's productivity. In order to do so, this study applies a system dynamics approach, which can study complex system by exploring underlying relationships and connections between the components of a system that normally are not discovered by the input-output-process type of models used in organizational studies.

III. RESEARCH METHODOLOGY

The methodological approach of this research is based on the system dynamics (SD), as a modelling and simulation methodology enables to model complex system considering all the influencing factors [19]. There are many modelling techniques developed and used so far, according to the modelling goal and perspective. However, system dynamics modelling chosen for this research because it provides a systematic method for description, exploration and analysis about the dynamic behavior of complex systems [18]. SD methodology has been applied by many researchers [19][20] [24][25] for studying and managing complex feedback system, where feedback is understood as a closed sequence of causal relationships. The concept of a feedback loop reveals that any actor in a system will eventually be affected by its own action.

A number of diagramming tools are used in SD to capture the structure of systems, including causal scale/influence diagrams, stock and flows. Each causal link is assigned a polarity, either positive or negative to represent a causal relationship between two factors. It indicates how the dependent variable changes when the independent variable changes. The important loops are highlighted by a loop identifier, which shows whether the loop is a '+' (reinforcing) or '-' (balancing) feedback [18].

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A. Identification of different factors affecting agile teamwork productivity

Data collection: The model developed for this work is based on data collected from the software companies in Bangladesh. There are three important objectives of collecting information; to determine what factors affected productivity of agile team members, to determine how these factors impacting project productivity in the team's perception and to determine the significance of the factors. Identification of the factors was initially carried out through an intensive literature review. A set of semi-structured interviews and face-to-face discussions were also conducted with twelve key project members from four software companies including project managers, scrum masters, developers, project owners, and considering also different experience profiles.

Using the factors identified in this first step, a questionnaire [26] was developed. In an attempt to identify the perceived influencing factors and their impact on agile team members, the survey questionnaire was distributed to a total of seventeen software companies in Bangladesh. The company selection criteria for this preliminary study were: companies using agile methods for at least 1 year, developing software for both offshore and local market, and top listed companies in Bangladesh.

Data were collected throughout a period of three months in 2017 (January-March). In order to ensure the quality of data, team members were all self-selected by their organization based on their work roles as members of existing agile teams. Therefore, participants responded to survey questionnaires were already aware of agile team environment and mostly experienced. The filled-in questionnaires were then analysed to identify factors, which have major influences on agile teamwork productivity. Currently, more software companies are being requested to participate in this survey, as the plan is to collect more than 100 responses from different agile teams.

B. Selection of factors for inclusion in the model

Data analysis: Factors affecting agile teamwork productivity are rarely independent of the others, but a set of factors interacting with each other to build the final result [7]. The important factors identified in literature and interviews were taken as a starting point for the system approach in this research. In total, 38 factors were chosen for analysis even though not all of them are presented in this paper. In order to create a system model to analyse the teamwork productivity, it is required to determine the importance of the individual factors, their correlation with one another and their effects on productivity itself. The agile team members were asked to fill in the questionnaire to indicate the strength (high, medium or low) of the factors that they perceived influenced their productivity [25].

The procedure followed to extract the agile team member's perception of the influence factors affecting their productivity can be summarized in the following steps:

1. Convert the qualitative scale to a quantitative one. The qualitative scale of high, medium or low was converted to a number scale of 3, 2, and 1, respectively.

TABLE I. ARITHMETIC MEAN OF QUESTIONNAIRE RESULTS FROM FREQUENCY ANALYSIS

SL	Factor	Mean	SL	Factor	Mean
1	Culture	**2.23**	20	What is the staff turnover rate in the project	**1.82**
2	Staffing	**2.76**	21	Reuse	**2.17**
3	Size of team	**2.29**	22	What is the software reuse level in the project	**2.00**
4	Project complexity	**2.23**	23	Goals	**2.29**
5	Team Leadership	**2.52**	24	Intra group wage inequality	**1.94**
6	Mutual performance monitoring	**2.41**	25	Team measurement	**2.17**
7	Backup Behaviour	**2.41**	26	Self-management	**2.17**
8	Team orientation	**2.52**	27	Task variety and Innovation	**2.41**
9	Adaptability	**2.35**	28	External Dependencies	**2.17**
10	Feedback	**2.70**	29	Tools usage	**2.29**
11	Mutual trust	**2.76**	30	Programming language	**2.05**
12	Coordination	**2.70**	31	Schedule pressure	**2.29**
13	Communication	**2.82**	32	Impact of Pair programming on productivity	**2.11**
14	Staff are appreciated for working long hours	**1.76**	33	Resource constraints	**2.41**
15	Staff are rewarded (then or later) for working long hours	**2.11**	34	Project Management	**2.58**
16	Adequate technical training for team	**2.41**	35	Motivation	**2.58**
17	Adequate team skills training for team	**2.35**	36	External project factors	**2.41**
18	Team member turnover	**1.64**	37	Dealing with cultural differences among offshore organizations	**2.17**
19	Key personnel stayed throughout the project	**2.23**	38	Working environment	**2.35**

2. Find the total score of each factor for frequency analysis. Then, the arithmetic mean of the total counts was calculated to eliminate the factors below the average (Table. 1) mean.

IV. SURVEY RESULTS

Characteristics of the sample software companies can be found in Table II. Fig. 1 presents the agile practices adopted by the participating software companies and it shows daily stand up meeting mostly used by all of them. Fig. 2 shows that lack of management support (e.g., resource constraint, team design choice and motivation) is the main reason for failure in agile projects.

In most of the interviews, the team members could not define productivity as their performance measurement. Most of them mentioned that team management has their own ways of measuring productivity. Although at the end of the project, the management assessed their productivity on the basis of timeliness and quantity. At the same time, ten interviewees and survey respondents (Fig. 3) also mentioned customer satisfaction as a criterion for measuring or perceiving productivity. Customer satisfaction is very important to software development companies in Bangladesh as a rising market for outsourced software destination. According the product owner interview, dealing with cultural differences among offshore organisation influences teamwork productivity. Two main reasons behind this are time and culture differences.

TABLE II. CHARACTERISTICS OF PARTICIPATING SOFTWARE COMPANIES

Characteristic	Category	Number	%
Main team assignment	Development project	10	58.82
	Maintenance project	7	41.17
Team role	Project manager	4	23.52
	Developer	6	35.29
	Software engineer	3	17.65
	Team lead	2	11.77
	Quality assurance engineer	2	11.77
Experience in agile practice	1-2 years	8	47.8
	2-5 years	7	41.2
	More than 5 years	2	11.8
Development method	Scrum	17	100
Size of the company (person)	30-50	2	12
	50-100	1	6
	100-150	5	29
	150-200	6	35
	200-250	1	6
	250-300	1	6
	More than 300	1	6

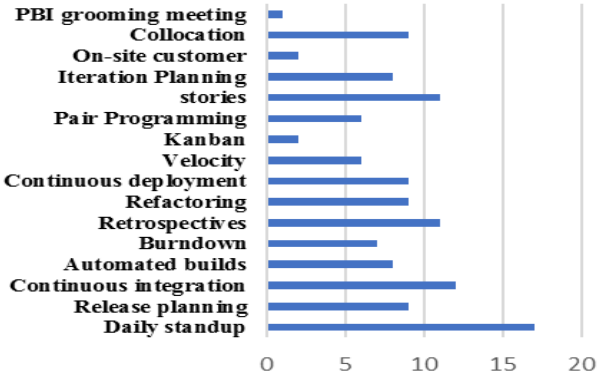

Figure 1. Agile practices adopted in software companies

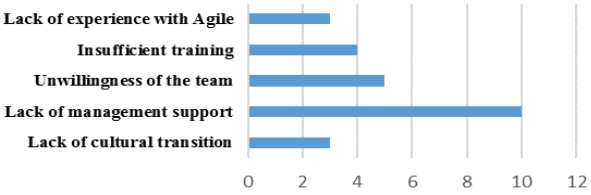

Figure 2. Main reasons for failure in agile projects

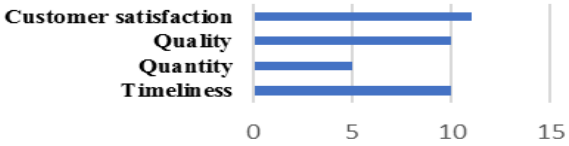

Figure 3. Criterion for measuring or perceiving productivity

Figure 4. Agile team perceived productivity influence factors

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Sometimes it becomes difficult to keep contact with the offshore client on urgent issues due to time difference between places. Moreover, offshore client's expectations are different, both in terms of their general culture and their views on life and work. Project developed within western cultures are different from eastern cultures. For example, daily traffic condition consumes most of the working time in Bangladesh, which makes the developers less motivated. Since, staff are not rewarded enough for working long hours. However, schedule pressure can be easily dealt with overtime working because it costs less in Bangladesh.

Five interviewees (project leads and managers) also mentioned that culture is a big barrier for working in an agile team. This factor affects communication between team members. In addition, sometimes language barrier hinders communication. Transitioning from individual work to self-management team requires a reorientation not only by developers but also by management. This changeover takes time and resources. For this reason, these project managers prefer freshers as a team member. Their software companies like to groom up with training than changing mind set up of the team members. Besides that, self-management and adaptability are considered key for agile development. But these two factors have less influence (Table. 1) on agile teamwork productivity and mostly depends on competent project management.

Fig. 4 provides highlights of the most influencing productivity factors that are perceived by the agile team members. This study results show that agile teamwork is highly dependent on team effectiveness. Project manager is usually a technical lead and many management decisions are made by the top management since the majority of the projects are outsourced projects. Their offshore clients' satisfaction (external factors dependency) is very important to them. Team leadership and team orientation are very important for teamwork motivation. The factors impacting on agile teamwork productivity mentioned by the team members suggested that feedback, team orientation, communication, coordination and mutual trust improve team effectiveness. Eventually, this will enable team to learn how to effectively manage relation within team in order to become more productive.

V. QUALITATIVE MODELLING OF AGILE SOFTWARE DEVELOPMENT TEAMWORK PRODUCTIVITY

Each factor that affects agile teamwork productivity is itself affected by other factors [9]. Some factors may be the result of the same cause [19]. Fig. 5 presents the overall conceptual model of agile teamwork productivity. It shows all the influence factor's affect found in this study. It can be seen in Fig. 5 that the arrows between every two variables differ in sign (positive or negative) to express direct or indirect cause-effect relationships between the two variables they connect.

Distinct from previous studies [7][24] this model represents the team dynamics which is a collection of "soft factors" [23] and effects related to agile methods that influence the teamwork's productivity. The soft factors that can affect the software development teamwork productivity include motivation, team management efficiency, customer satisfaction, skillfulness and team effectiveness (communication, coordination, adaptability, feedback, leadership, team orientation, mutual trust, monitoring, backup-behavior, self-management). Teams require a complex mixture of factors that include organizational support, individual skills and also teamwork skills [10] to work effectively. This study also found these are the most influential productivity factors from the agile team's perspective. Within the model (see Fig. 5), it is shown that team effectiveness is influenced by team management, motivation, team design, skillfulness, resource constraint, communication and coordination. Team effectiveness can be improved by team learning processes which include activities such as feedback, mutual performance monitoring and back-up behavior. These learning activities are likely to create a positive change and to influence the productivity. On the other hand, motivation influenced by team management, reward, goal, salary, working environment, morale and external factor (customer satisfaction).

Fig. 5 illustrates that motivation is positively related to team effectiveness. A motivated team is much more likely to be involved with the learning oriented activities to develop better interpersonal relations and that eventually will increase the team effectiveness. On the other hand, lack of team management skill negatively influences teamwork productivity. It mainly refers to team design choice and resource constraint. Another factor that influences skillfulness is pair programming; however, this factor is not encouraged in Bangladeshi software companies. Management does not want to engage two resources for single work due to increase in expenses. It is mostly practiced by the developers when they need assistance to complete a difficult work.

Getting the right person with suitable skills and knowledge for an agile team is a difficult job for the software companies in Bangladesh. Staffing (right person selected) happened to be as one of the most important factors impacting teamwork productivity, as Table I and Fig. 4 show. Consequently, team design choice became a significant influencing factor for agile teamwork productivity (Fig. 5). It affects the amount of knowledge that team members must apply to improve the team effectiveness (Fig. 5).

VI. LIMITATIONS OF THE STUDY

There are a number of limitations to this study. First, this study was limited to 17 respondents and 12 interviewees from 17 software companies only. It was challenging to get access to more software companies due to time constraint. Respondents were carefully chosen from different roles within the agile team in order to get different perspectives of productivity in the context of Bangladesh software Industry.

Another limitation of this study is the agile team members' perceptions used as a response. However, with survey, this study relies on what the respondents provided to the researcher. It is possible that the respondents' perception

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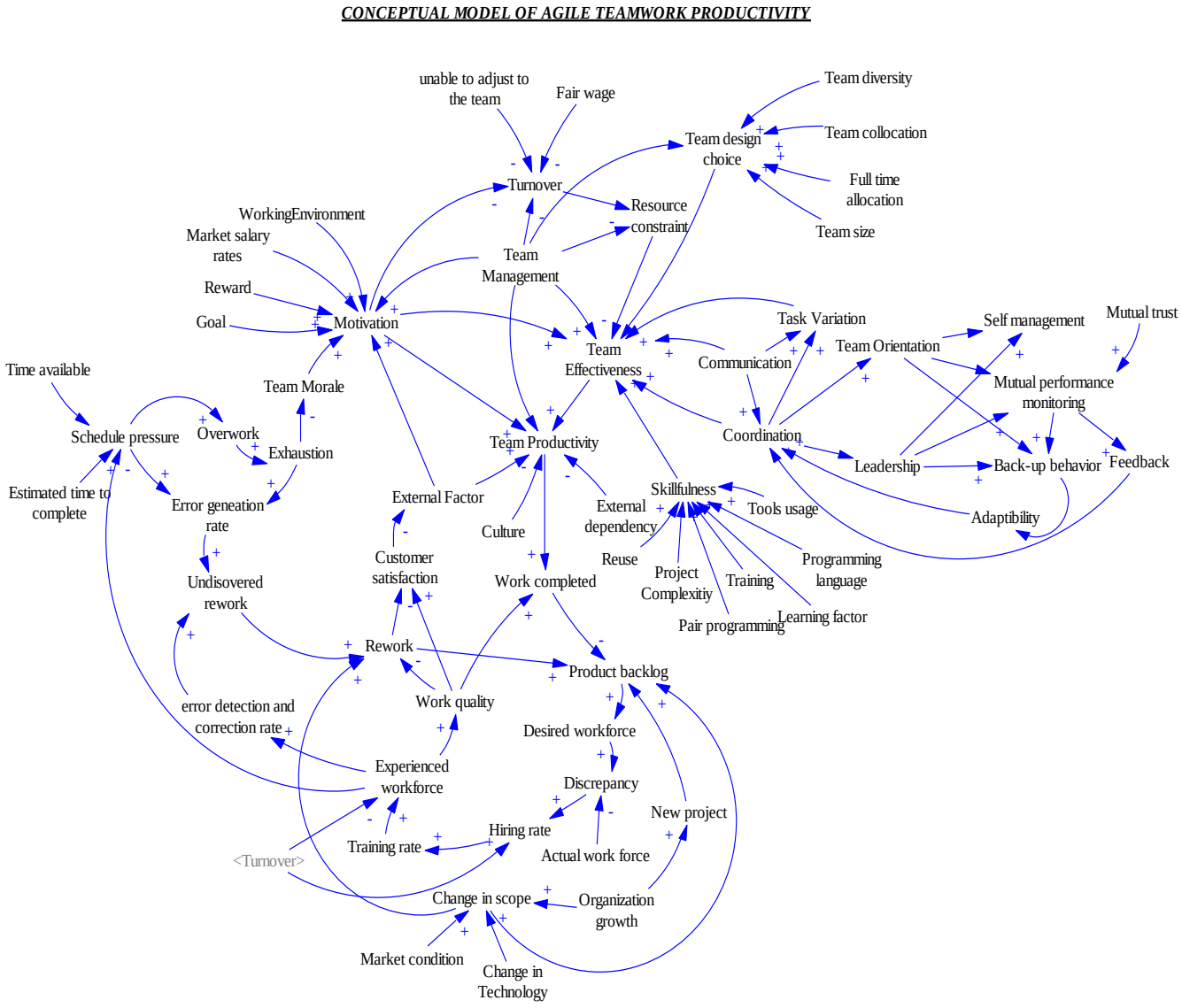

Figure 5. Overall conceptual model of Agile teamwork productivity

may change and be different after the end of the project. To minimise the impact of this effect, the survey and interviewees' responses were compared for factors selection to include in the model. The questionnaire used for this study had been used successfully in other research [9][22] and was developed after a detailed literature review. Some of the questions were included in the survey after getting knowledge about the working conditions of software companies in Bangladesh from the interview sessions.

Finally, this conceptual model certainly has its limitations and is not complete because it only focuses on the influence factors. The multiple feedback processes and delays are not incorporated in this model.

VII. CONCLUSION AND FUTURE WORK

Teamwork productivity determines the overall project performance in an agile software development process. Therefore, researchers have gained increasing interest in studying agile teams' productivity. Agile team members should be taught to interpret and manage productivity factors regularly as they are self-managed.

The researchers concluded that productivity improvement programs would become effective only if all the variables are simultaneously controlled and monitored. One effective solution to improve productivity is to look into the factors influencing productivity and also have a dynamic strategical model that tells the project manager in advance the degree of impact that these factors will have on team productivity. In order to achieve that, the main factors

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that affect teamwork productivity were determined. The findings of this stage are the main influencing factors which are team effectiveness, team management, motivation and customer satisfaction. Lack of agile team management support was found to be the most mentioned reason for failed agile project. Most followed agile method was SCRUM for all the respondents. Among agile practices, daily stand-up meeting and continuous integration were the most cited practices impacting teamwork productivity. Customer satisfaction was found as main criterion for measuring or perceiving productivity by the interviewees and survey respondents.

As a future work, the soft factors are to be quantified to incorporate in system dynamics model. The proposed system dynamics model will provide more strategic insights and understanding about the effectiveness of different managerial policies based on non-straight forward cause-effect relationships hidden in the system. Furthermore, this qualitative CLD will be used as a basis for a stock and flow model development of the quantitative SD method. Further research need to be conducted to validate the conceptual model against a real-world agile software development project.

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