

Organizing Software Project Control Practices

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Abstract—The major challenge for software project control is to adapt to the associated control practices in order to achieve sustainability for the software project. This paper reviews software project control practices in a number of control perspectives, namely organizational controls, project management, software engineering and cybernetic management. The aim is to extend the concept of controlling software project towards adapting appropriate control practices. A number of basic control components are identified to better understand the control practices. We found that (a) control elements create its own complexities on software project control; (b) communication between the controller and contreee is important in identifying and understanding control direction; (c) each individual has their own roles in practicing software project control; and (d) there is a needs for organizing complexities in managing software project control practices. The principal recommendation is to understand proper control practices in studies of various complex situations of software project control.

Index Terms—Control Components, Cybernetics, Software Process, Software Project Control.

I. INTRODUCTION

Software project control plays a major role in developing a large-scale, long-life software, in a co-evolution environment. Co-evolution is defined as changes of business processes and evolution of software that supports it, which evolve sympathetically but at different rates [1]. There is a need for software project to be able to control and trigger suitable tasks dynamically [2]-[5], either from the business perspective or from the software perspective until the software is unable to support the evolution of the business processes.

Subdividing a large-scale project into smaller projects where each subproject representing a different function from a master project, can make it easier for managing and controlling software project [6],[7]. During software development, when identified subproject is ready to be

deployed, the organization can start using the application software for their business process. Changes in the business process may involve another software development. An ongoing (development or maintenance) project is implemented from time to time to ensure the application software and software that supports it is functioning well [8],[9]. Based on Ashby's Law of Requisite Variety [10], interrelated tasks between software project control, software development and software maintenance will possibly lead to a more complex phenomenon. Therefore, the major challenge for software project control is to be able to adapt to appropriate control tasks in a complex environment.

There are various control perspectives involved in software projects, such as organizational control, project management, software engineering and cybernetic management as shown in Fig. 1 [11]-[14]. The organizational control is used for influencing project task and project team behavior [11],[15],[16]. Project management act as a controller who drives the software project. Software engineering controls the project from the aspect of methods and techniques of developing software [12]. While cybernetic management is concerned in producing all sets of possible control behaviors [14].

In this study, the controller refers to person(s) responsible for designing and implementing controls, while the contreee refers to person(s) executing the project. A person can become a controller for his subordinate and at the same time he can become a contreee for his superior. Each perspective has their own purpose and practices in controlling software project. So does the controller and contreee.

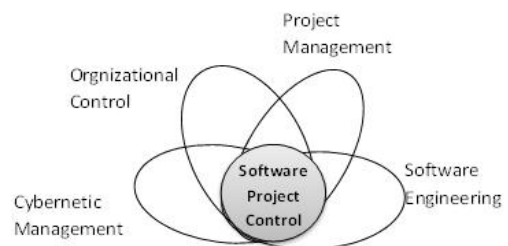


Fig. 1. Various control perspective

In this paper, software project control practices are explored, compiled, analyzed and organized. Software project control must be able to control and trigger the suitable task sympathetically between software development and software maintenance [2]-[5]. Various aspects need to be considered in establishing and setting up suitable control mechanism. Simultaneously, software project control also must have the ability to differentiate between elements that need and need not be controlled even though they are controllable [17]. Each phases of software processes need to be controlled dynamically [18].

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Hence, the objective of this paper is to extend the concept of controlling software project towards adapting the appropriate control practices in order to sustain the success of software project within the complexity of software project control itself. We proposed cybernetic management approach for software project control practices in understanding the capabilities of practicing software project control because of its act as an alternative to management control system [19] and also of its main concern in science of control and communication [14],[20],[21].

II. LITERATURE REVIEW

A. Organizational Controls

The purpose of the organizational control is to influence project task, project team's behavior and decision making in a manner that is consistent with organizational objectives [11], [15],[16],[22]. Top management uses organizational control as a tool to explain the project goal, role and task involved in a project [11],[16]. Simultaneously, the organizational control also helps in coordinating project task [16] and also interaction with users [24] within the project team.

Various control mode and mechanism can be applied [25]; [26] such as bureaucratic control, management control, agency theory and informal control. Top management or superior used bureaucratic control [27] to explain and to issue control directions such as rules and procedure to be followed by project team. Plans are communicated downward to inform project manager the management control process if actions or outcomes are not inline with the project objectives [28]. This include observing performance, signing value to the performance and comparing value to the rules and procedure such as schedules, reporting, goal setting and formal meetings [11],[29]. Progress reports are then communicate to inform the status of project progress to various constituencies.

Hence, used of management control can help project manager to ensure that individuals and project team can behave and make decision that are consistent with the organization's objectives and strategies [30]. A part from that, management control also can be used as a tools for reward system [31],[32], strategic control implementation [31],[28] and also as a guide towards organizational learning [28].

According to Simons [28], project manager used management control personally and regularly in the decisions of subordinates. Unfortunately, principal-agent problem arises when relationship of contrast self-interests between controller and controlee exist [33]-[35]. This is known as agency theory [35]. Controller and controlee will performed different actions due to their own differences of roles, functions and responsibilities in project organization.

Thus, each controller and controlee must have their own informal control. Informal control rely more on 'unwritten practice code' related to people and communication such as social values, common beliefs or culture among project team or individuals including informal meeting [36]. They share common goals. And simultaneously, they established their own specific goals, objectives and standards. They can work

independently and monitor their own progress. Hence, organizing formal and informal control practices throughout project lifecycle can influence project information and project performance [36]. Besides, user(s)' involvement and participation can also give an impact to the performance of project task, project team's behavior and decision making [37]. Hence, project manager must have the ability in controlling users satisfaction [38].

Therefore, whether the project organization is permanent [16] or temporary [39],[40], organizational control is implemented at each management level of software project [11],[29]. Organizational control is used in dealing with organizational problems, particularly due to the complexities of communication among the project team members [35] and changes of interaction in an uncertainty of project environment. Even though the project manager is the main project controller, each individual in a project is a controller in their own right [11]. The controller should be clear of interdependencies between the role of control and their role in executing project tasks. And also the need to establish and maintain the relationship within and beyond the project organization [41].

B. Project Management

Project management is part of a management discipline [42]. Project management is meant to control software project according to project plan. Project management will act as a controller to drive project control systems [13]. The controller should provide procedures, rules and guidelines for control activities [30],[43]. Controllers must also ensure that suitable control activities chosen not only able to control software processes [17] but also are able to produce progress report [44].

Progress reports that are produced shall describe the operations and activities of the software project. Various stages of reporting processes must gone through from project team climbing up to management team and also to related users either in writing or verbal communication. Different level of reporting processes required different approach of presentation. According to Thomson and friends [44], controller's ability in making decisions can be influence by the quality of project reporting. Several researchers [32],[44]- [46] have argued on project reporting behavior in order to simultaneously satisfied various constituencies. For example, top management only interested on the project stability even though project status is influence by various environment [47]. Whereas project team always presenting raw data and with their own conclusion [48]. They can manipulate data as to show positive value [49],[50]. Besides, reporting is more on explanation rather than correction [49].

Therefore, project manager should know how to establish suitable control and communication environments as to avoid the present of misreporting. Hence, Thompson and friends [44] suggest that senior management and project manager should identify potential reporting problem through various approach such as periodic audit and multiple sources of status information.

According to Bryde and Robinson [51], there exist a relationship between project management and the principles of total quality management. Generally, the project activities should comply with the quality management cycle which is

Plan-Do-Check-Act for their control processes [30],[51], [52]. Project management will provide procedures, rules and guidelines [53]. Control processes will compare the project current status with various project plans. Each process will be connected to the input activities, output activities and tools and techniques according to project management knowledge areas [30]. Unfortunately, control processes adapted more towards the stability of the internal project environment, and not much towards the disturbances from the external environment [54]. White [54] argue upon the differences approach between risk management and disturbances control.

According to Henri Fayol [55], the controller must exist at each management level. Each controller has their own activities and use different control practices [35],[56]. However, not all activities are control practices. Therefore, controllers must be able to differentiate between control and non-control practices [17] and procedures in order to influence the control process itself.

C. Software Engineering

Software engineering is define as a “Systematic approach to the analysis, design, assessment, implementation, test, maintenance and reengineering of software, that is, the application of engineering to software” [57]. While software process is identified as partially ordered sets of activities undertaken to control, develop and maintain software systems [6],[7].

Controlling software processes can be referred as ability to measure software performance and determine level of software functionality [12]. Software engineering used software measurement as a tool in understanding software processes [58]. And simultaneously, software processes require software engineering’s methodology and guidance related to its own software behavior [9],[59]. Since co-evolution between business process and software can influence concurrently the implementation of software processes, hence, understanding software performance sympathetically, can help us in identifying the right control elements of software process throughout software project lifecycle.

According to Cai and friends [56], software itself can act as a controller and also as a contreee against software process. Therefore, a well defined software process can help in developing and triggering suitable tasks sympathetically between software development and software maintenance [60].

D. Cybernetic Management

Cybernetics, which is also known as the science of communication and control in the animal and the machine, is concern in producing all sets of possible control behaviors [10]. Cybernetics studies the complexity of information flow through a system and the way in which that information is used by the system as a mean of controlling itself. Cybernetics uses the control theory approach to describe, understand and control behavior of complex systems [10] and also can be used to discover control activities that is needed [21].

Science of cybernetics is than evolved into science of effective organization which is also known as cybernetic management or Viable System Model [21]. Stafford Beer

created it based on the human nervous system, Ashby’s Law of Requisite Varieties and General System Theory [14],[20],[21].

Cybernetic management consist of three main interactive elements which are Environmental, Operational and Managerial. As the Environmental changes, the organization must respond. This will usually require a change in the Operation to balance the Environmental changes and then Managerial will also have to adapt as it has to be in balance with its Operation [14][20].

These three main elements is then sub-divided into five recursive system. Each system can communicate up and down in their organizational level to seek balance between vertical and horizontal control variable [14], [20],[61],[62]. Each component has their own controller that need to interact effectively in their own environment [63]. They have their own control object and information. A controller can only respond to a relatively small number of possible states in its own environment. And uses contreee to respond indirectly to all the others.

Environment plays an important role in software project stability [1]. According to Beer [14],[20], environments of the viable system consist of operational environment of the system, accepted environment of the organization and problematic environment of the organization. This include environment of software co-evolution [1].

According to Ashby’s Law of Requisite Variety, only variety can absorb variety [10]. Variety is number of possible states of controlling element whose complexity is what we want to measure [14]. If the number of variety increases, complexity of the project rises [14]. Nature, function and purpose of the system can help in identifying requisite variety in every situation [21]. It shows that requisite variety should exist in project information.

III. ORGANIZING SOFTWARE PROJECT CONTROL

From the above discussion, software project control components are structured and organized.

A. Structuring software project control components

Structuring control components can help us in aligning software project control practices with the software project activities Beer [21]. Software project control components are then, mapped with various control disciplines and environment where evolvment of business processes and software evolution exists. As such, existence of interrelatedness, interdependency and differentiation within control elements can be seen as in Fig 2. Marshal and friends [64] define this situation as complexity which is the main concern of this study.

Environ- ment such as (i) Changes of business (ii) Process Software evolution	Software project control practices				
	Organiza- tional control	Project manage- ment	Software engineering		
			Develop- ment	Maintenance	
				System software	Application software
Existence of interrelatedness, interdependency and differentiation within control elements which contribute to software project control complexities					

Fig. 2. Existence of complex situation in Software Project Control

Based on Control Theory [65], control components are identified and described as in Table 1. Descriptions of control components can help us in outlining the purpose of software project control practices.

TABLE I: THE CONTROL COMPONENT'S DESCRIPTIONS

Component(s)	Description
Controller	person(s) responsible for designing and implementing controls
Controllee	person(s) responsible for software executing in the project
Controlled Variable	process variable, whose value the system is intended to control
Control Objectives	A statement of the desired result or purpose to be achieved by implementing control procedures in a particular process
Control process	A continuous flow between measurement, comparison, and action.
Project Information	Project progress status

We combined and compiled basic control components from organizational control, project management and software engineering perspective as a basic guide in identifying proper software project control practices. These components are then structured according to Table I as in Table II.

TABLE II: BASIC CONTROL COMPONENTS IN SOFTWARE PROJECT CONTROL

Component (s)	Organizational control	Project management	Software engineering
Controller	Top Management, Proj. Manager, Proj. Team, Individual		
Controllee	Project Manager, Project Team, Individual		
Control object	Project goal, roles, function, project task, communication, environment	Tools, techniques, input activity, output activity	Methodology, software process, management process
Control Objectives	To influence people task and behavior To coordinate project task and resources	To control project activities according to project plan	To control software performance and functionality
Control process	Rules, procedure, work break down, recruitment, contract, performance measurement	Rules, procedure, quality assurance, information flow, project task, progress report, performance measurement	Software measurement, development process, quality assurance
Project Information	Project team performance and capability, project performance	Project progress, project performance, software quality	Project progress, project performance, software quality
Problematic	Project Information, People interests	Control process, project activities	Software process, project activities

Consequently, levels of management involves in software project is also be structured and organized. Each management levels have their own controller with their own roles, functions and behavior [66].

Various control modes and control mechanisms can be used to communicate project information among each other [47],[49],[50],[67],[68]. Project information will then communicate to and fro from technical team, managerial

team, project managers and users or stakeholders. Henderson and Lee [16] states that, project team communication can influence the performance of software process. Varieties of control mode can be applied in various levels of management. We proposed some related control modes in relation to different levels of management in software project organization. Its hierarchy as shown in Fig 3.

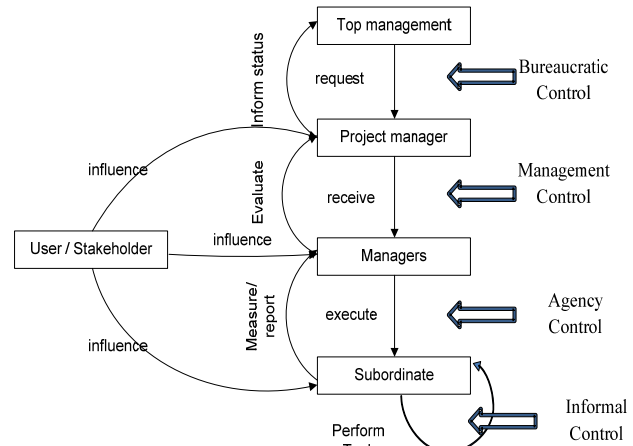


Fig. 3. Structuring Levels of software project controller

Using the purpose of unit of analysis [69] as a guide to identify control classification, mode and mechanism. Unit of analysis is used to clarify the needs of control objectives in each management level. Table III illustrate some of the control classification and control mode in various unit of analysis.

TABLE III: CONTROL CLASSIFICATION AND CONTROL MODE

Sour ce	Unit of analysis	Control practices	Control classification	Control mode/mechanism
[26], [70]	Organization (top management, project manager, user)	Strategy made as an attempt to increase the controllee's probability to act towards project objective	Formal control Informal control	Bureaucratic Self-control
[16]	Project management (project manager, project team)	An attempt to increase the individual's probability of behaviour toward project goal	Management Project team	Management control Agency control Self-control
[33]	Software activity	To ensure that project activities can be coordinated To reduce project disturbances due to external environment	Formal control Informal control	Standard Planning Formal adjustment Informal adjustment

B. Organizing Software Project Control Practices

As various researchers [19],[70],[72] have successfully tested and used Beer's Model [14],[20],[63] in diagnosing sustainability of their subject research over a wide range of complex real world situations, we found that Beer's Model also can give us credit to this study. Using the interpretive approach based on Beer's Model we develop a benchmark in

organizing software project control practices as in Table IV. It consist of Beer's Model's relationship between systems functions and its objective of controlling the systems where the information is needed for supporting software project control activities in order to keep software project success

and survive within the co-evolution situation. We include also Table II and Table III inside Table IV to form a relationship within cybernetic management in order to organized the practices.

TABLE IV : RELATIONSHIP BETWEEN CYBERNETIC MANAGEMENT, CONTROL OBJECTIVE, CONTROL PRACTICES AND CONTROL MODE

Systems	Functions	Control Objective	Control Practices	Control Mode
S5 Policy	Policy-making function. Provide clarity about the overall direction, values and purpose of the organizational unit.	To influence project direction in dealing with co evolution situation	Practices to influence people task and behavior by providing clarity about Project goal, roles, function, project task. Strategy made as an attempt to increase the controlees' probability to act towards project objective.	Beaucratic Control Self-control
S4 Intelligence	Future focus to ensure adaptation being applied due to environmental changes and provide primary activity relevant to future environment.	To create and enhance software project regulation adaptation	Practices for software changes due to changes in environment	Management control
S3 Control	Acts as a hinge between current operations and future planning and software process. Resources are negotiated, instructions are issued and project information from S1 flow upwards in order to keep top management in touch with project status.	To regulate internal stability	Practices for managing and resource allocation for software process. Practices to control project activities to increase the individual's probability of behavior toward project goal according to project plan	Manage-ment control Agency control Self-control
S3* Audit	Received accountability report of S1 project status.	To audit software processes activities.	Practices to audit software processes activities	
S2 Coordination	A place where functions and primary operations are coordinated by mutual adjustment. Common standard, approaches and values can be shared among S1. Dealing with S1's complexities environment.	To assist internal stability regulation	Practices to ensure that project task and resources can be coordinate	Standard Planning Formal adjustment Informal adjustment
S1 Implementation	Primary activities for implementing software process. These systems are responsible for completing work task of software process	To control software process implementation	Practices to control software development and software maintenance implementation. Practices to reduce project disturbances due to external environment	Management control Agency control Self-control

Organizing software project control practices can help us observed the actual software project organization related to the viable system environmental. As mention earlier, viable system environment are consist of operational environment of the system, accepted environment of the organization and problematic environment of the organization.

Due to these environment, Table IV, Fig 2 and Fig 3, software project control is then mapped onto the Beer's scientific model. This model is directly used to organize software project control activities in terms of its viability based on its specific and terminological mapping. It shows that the interrelatedness, interdependency and differentiation within control elements of software project control practices can structured and organized as in Fig 4.

Finally, we mapped Fig. 4 onto Fig. 2 and as a result, Fig. 5 is being produced.

IV. DISCUSSION

This study has identified several problems in practising software project control. First, existence of various control directives, either formal or informal from the various control

perspectives. Secondly, presence of interrelatedness, interdependency and differentiation within control elements, known as complexity of software project control [64]. Thirdly, the software project control deals with complex problems of software process evolution. Fourth, ability to differentiate elements that need and need not to be controlled eventhough they are controllable. And finally, the controller is part of the software project control and the controller evolves together with the software process evolution [14]. Software project viability can be diagnosed with the help of the scientific model of cybernetic management.

Prior research has shown that software project control has been used extensively in software project management and it can be classified into controlling deviation of project activities [68], influencing human factors [11],[16], reducing factors of project and project management success [74] and portfolios of control [17]. But not much disscussion has been made on the control practices itself [71].

This study shows that, in order to have the continuation of software processes, the software project control practices must have the ability to control and trigger suitable tasks dynamically from the day the project begins until the day the

system software cannot be able to adapt to the business processes anymore. Evolution of the business process and software process is identified as part of the project environment that can influence the viability of the software project.

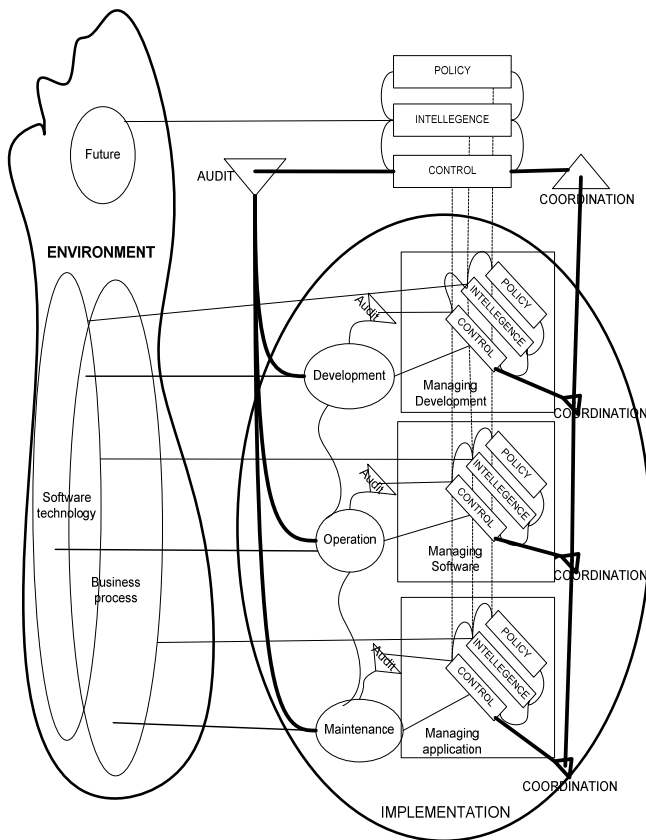


Fig. 4. Diagnosing Software Project Control Practices

Environment such as	Software project control practices				
	Organizational control	Project management	Software engineering		
			Development	Maintenance	
				System software	Application software
(i) Changes of business					
(ii) Process Software evolution				System 1 - Implementation	

Fig. 5. Organizing Software Project Control Practices

V. CONCLUSION

Each individual within software project organization plays a major role in controlling software project towards sustainability of the success of software project. This study shows that software project control practices act as a major player starts from the initiation phase, development phase, maintenance phase until the system software cannot adapt to the business process anymore. Various control mode and mechanism can be used either on organizational level, management level or even individual level. Project manager has to identify the appropriate sets of controls in performing assigned tasks appropriately.

This study also finds that communication between the controller and contreee is important in identifying and

understanding control direction and handling project information. Different level of reporting processes are required due to different approach of presentation

It is crucial to recognize project environment as part of software project component as we can follow through their evolution and its impact towards the software project. It is important to view software project control from the perspective of control practices in order to manage control activities. Hence software project control should also have the capabilities to identify environmental elements that trigger the needs to change control practices.

This paper shows that software project control can also be assessed through the science of control and communication which follows the cybernetics principle [14]. Hence, there is a need to extend this work. First, is to develop a simple control system to visualize the communications and control practices between the controller and the contreee. Second, is to develop a more comprehensive control system. Seeking a various management approach of controlling software project practices can help organization in identifying and understanding the capabilities of project manager in practising software project control.

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