instances marked in red. The heating coil valve should have been modulating only when the heat recovery by-pass damper is completely closed according to the design intent, however both are open above 0% for the instances marked in red. Majority of these instances occurred in September and October 2013 when the room temperatures modulated between 20°C to 26°C.

It is impossible to assess why the heat exchanger does not reach its maximum capacity by only looking at the room temperatures, as the heating requirement would be compensated by the heating coil. Hence it is important to look at the control relationship between the heating coil valve and the bypass damper which may not always be explicitly described in the SOOs. In the case example being studied, the control relationship was determined from the pseudo-code developed based on the discussion with the commissioning engineer for the project. Formal representation of SOOs can be used to clearly interpret all the control relationships required to implement the design intent.

LESSONS LEARNED FROM THE DEVIATION ANALYSIS

Identifying the anomalies in the implemented controls ensures that HVAC systems perform according to their designed controls and can help save energy (Baumann, 2003). Salsburgy et al. described two testing approaches for commissioning HVAC control systems (Salsbury et al., 2003)**:**

(1)Passive tests: Testing approaches that evaluate the implemented controls by only observing the normal system functioning. The relevant variables of the controls are selected and the corresponding sensor data is recorded for analysis every day**;**

(2)Active tests: Testing approaches within which the normal functioning of the system is disturbed to verify the responses by various system components to the disturbances. The component responses are verified against the expected behavior based on the designed controls.

It is essential to interpret the design intent from the SOOs to compare against the actual system functioning for both of the testing approaches. Previous work in this research identified the challenges in interpreting the design intent from the SOOs due to the absence of a guideline that states the various information items that are to be included in the SOOs (Sunnam et al., 2013). For example, the sensor that corresponds to the parameter that is directly associated to the controller of the heating coil valve is not explicitly stated in the extract from the SOOs for the studied AHU.

> *"The return temperature of the heating coil is controlled to a minimum temperature set point. When the system is not functioning, the controller has direct access to the Heating coil valve. During the operation of the system, a maximum value is selected from the control values of the heating coil return water temperature controller and the supply air temperature controller."*

Hence, the challenges in interpreting the design intent of the controls also impede the controls testing tasks during commissioning. Formal representation of SOOs can help to clearly interpret the design intent that can be compared to the implemented controls.

The deviation analysis presented in this paper is an example of a passive test. It utilizes the trend data from the BAS and visually analyzes the system functioning for twelve months. Both the active and passive testing approaches help in identifying the differences in the implemented and designed controls. However, these diagnostic approaches give little information about the changes required for the implemented controls to eliminate the deviations. Formally associating the sensor data points to the respective control parameters can further help in identifying the changes that need to be made to the implemented controls in the event of deviations.

CONCLUSION

This paper highlights a need for the formal representation of SOOs and also formal approaches for comparing the design intent from the SOOs to the implemented controls. Presently, several challenges are associated with interpreting the design intent of HVAC controls from the SOOs, such as missing information items, missing set points, or insufficient descriptions. Hence the implemented controls cannot always be compared to the design intent during commissioning. The deviation analysis from the case study presented in this paper shows the importance of testing the implemented controls as they help identify control issues that may lead to energy wastages. Formal representation of SOOs can greatly improve this process of controls testing by enabling clear interpretation of the design intent. Also, the testing approaches used for commissioning the HVAC control systems presently do not clearly indicate the changes that are required to be made to resolve any identified deviations of the implemented controls from the design intent. The analysis of the case study shows that associating the trend data points from the BAS to the control parameters can be used to effectively identify any deviations of the designed and implemented controls. Once the correct implementation of the controls is established, the controls can further be optimized to achieve energy savings up to 35% (Wang et al., 2011). Future work will focus on formalizing the deviation analysis of the designed and implemented controls to exactly identify the changes that are needed to be made in the BAS programming in the event of any deviations.

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Implications of Micro-Management in Construction Projects-An Agent Based Modeling Approach

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Abstract

Micro-management refers to a management style whereby the managers closely observe and control the work details of subordinates or employees. Although micro-management generally has a negative connotation, the implications of adopting micro-management in construction projects remain unclear. This paper proposes the use of Agent Based Modeling (ABM) to investigate the impacts of micro-management on the efficiency, effectiveness, quality, and employee stress level in construction projects. A comprehensive simulation platform, Virtual Organizational Imitation for Construction Enterprises (VOICE), has been developed to simulate the proposal development of an EPC (Engineering, Procurement and Construction) project. The simulation results show that the micro-management has complex effects in the studied project, whereby decisional, behavioral, technical and institutional factors are interdependent. Micro-management in certain cases improves the efficiency and quality of proposal development. This paper contributes to the simulation studies in investigating social and behavioral problems in construction.

INTRODUCTION

Management styles can be grouped into two categories according to how coordinators involve themselves in the decision making and managerial actions; the categories are micro-management and not (Burton et al. 1998). Micro-management is the custom of being heavily engaged in the daily affairs and specific tasks of subordinates while the opposite is giving a degree of autonomy to subordinates. The organizational literature often refers to micro-management as a "bad management" practice (Alvesson and Sveningsson 2003). In general "*it takes away the decisions from the people that should take the decisions*" (Alvesson and Sveningsson 2003), and results in interference with productivity of people and the efficiency of projects and processes (Chambers 2009). Despite the evidence from general organizational literature, the implications of adopting micro-management in construction projects, however, remain unclear. This study proposes the use of Agent Based Modeling (ABM) to investigate the implications of micro-management in construction projects.

LITERATURE REVIEW

ABM is an emerging tool for use in social research to study human and organizational issues in a diversity of areas (North and Macal 2007). It is a computational method that builds a common environment for heterogeneous and autonomous agents to share, and allows the agents to simultaneously interact with each other for self-interest (Ligmann-Zielinska and Jankowski 2007). Unlike top-down modeling approaches (e.g., System Dynamics), in ABM the collective behavior of the simulated system is not predefined, but emerges from individual agents who act based on what they perceive to be their own interests. Thus, ABM is capable of reproducing the emergent properties of the studied systems (Macal and North 2007). ABM has been utilized by a small but growing community of scholars to tackle a range of difficult problems in the construction area, including engineering design (Soibelman and Pena-Mora 2000), project organizations and network (Du and El-Gafy 2010, 2012; Horii et al. 2005; Jin and Levitt 1996; Taylor and Levitt 2007), construction operations (Kim 2010; Mohamed and AbouRizk 2005; Watkins et al. 2009), project management (Christodoulou 2010), supply chain (Xue et al. 2005), and construction safety (Walsh and Sawhney 2004).

METHODOLOGY

An ABM model has been developed, namely Virtual Organizational Imitation for Construction Enterprises (VOICE). VOICE tailors Robbins' model of organizational behaviors (Robbins 2005) to suit construction organizations, with three main components modeled (Fig.1): (1) Work: construction organizations are project based organizations (PBOs), and thus projects and corresponding tasks are modeled as the sole input as that in Robbins' model; (2) Actors: project tasks are performed by the individuals in a construction organization, whose personalities, value and attitudinal factors affect the perceptions toward the tasks, leading to diverse micro-level behaviors directly related to the work performance; and (3) Organization: a variety of organizational structures that arranges lines of authority, work and communications, and allocates rights and duties. In addition, key performance indicators of project team performance are modeled as the main output. The architecture illustrated in Fig. 1 reflects the bottom-up process of organizational behavior (input-individual level process - group process - organizational process - output) as suggested by Robbins (2005). VOICE conceptualizes and integrates all components into a comprehensive and integral model. Table 1 summarizes the model rules of VOICE.

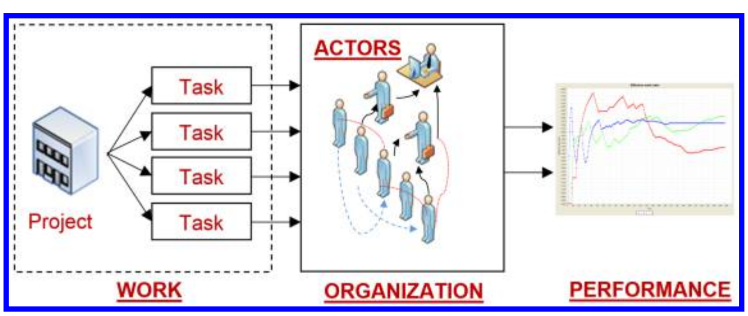

Figure 1. Model architecture of VOICE

Table 1. Summary of VOICE model rules

Work	• A project can be divided into a sequence of executable work efforts called tasks; • Multiple projects can be handled by a team simultaneously. • A task is the most basic executable work effort for a project team member; • Task amount is measured by "hours", i.e., how many hours it takes to finish a task by a team member with average competence; • Some tasks need approval from managers or president, or additional information before processing; If a task is dependent on another one which has not been finished, it cannot be processed;
Actors	There are three major roles of actors in a construction project team, including president, manager and staff member. In VOICE, an actor will first examine the situation. Then based on judgment on the situation and preference, a certain behavioral module will be triggered. • Prioritizing: An actor can only process one task at a time; therefore prior to further actions, an actor may order all tasks in hand based on the readings of their priorities; • Processing: Processing a task means reducing certain amount from the task every simulation tick. The amount reduced depends on task difficulty and competence of the actor. During this process, actors may commit mistakes shown as a mistake percentage of the task; • Submission: Once a task is finished and there is no successive actors (according to work process), the actor will submit the task to his/her superior; • Assigning: A manager may assign a task to his/her subordinates based on the assigning preference (e.g., speed driven or quality driven); • Requesting/approving: some tasks require approval from superiors; in this case, the actor will render this task to superiors, who approves the task or render it again to superiors based on the technical information of the task and authority level of the actor.; • Conflict management: If a conflict cannot be solved by staff members, it will be raised to the manager or coordinator for further actions; • Information exchange: If the available information for a task is less than the required information, the actor will send this task to another actor. After a while, the task will be returned to the requestor with necessary information; • Meeting: If the number of all exceptions in a team is bigger than the threshold of the president, a meeting will be held. After a meeting, all tasks are approved, information is provided, and exceptions are cleared; • Monitoring: If the mistake percentage of a task is bigger than the threshold of a staff member or a manager, it will be returned to the original actor, or will be corrected at a cost of additional time depending on the preference. • Correction/rework: If an actor receives a returned task marked as unqualified, he/she will redo it to improve quality. The time spent on correcting/redoing a task depends on the mistake percentage of the task and competence of the actor; • Stress-coping: An actor sums up total amount of tasks (burden) in hand – if this number is bigger than his/her capacity, he/she will suspend working, and return new tasks to the manager. The manager will reassign it to a staff member with smaller level of burden.
Organization	• Reporting structure: It is assumed that construction project team has a three level hierarchical organizational structure; • Work process: The procedure of processing a task; it shows the sequence of delivering a task among team members. It always starts from a manager; • Information flow: The channel connects information requestors and providers. Information only refers to task related information, i.e., that is needed for processing a task.

Performance	• Efficiency: Finished task amount per unit time (hour); • Effectiveness: Ratio of productive time versus total time. Productive time is defined as time directly spent on processing tasks; • Quality: The mistake percentage of a project, which equals weighted average of the mistake percentages of all its tasks. • Work pressure: Total work amount of tasks in hand for an actor;

SIMULATION ANALYSIS

A case study was conducted with a large EPC company denoted as A. In order to enhance its competitive power in the EPC market, Company A acquired an engineering design firm several years ago to design all of A's new EPC jobs. Proposal development is the responsibility of A's project proposal team. But because of the specialty of work, A's proposal team highly relies on the technical and quantity information from the engineering team to develop proposals. This study utilized VOICE to explore the implications of micro-management in the proposal development at A, especially with the interdepartmental cooperation between the engineering and proposal teams (Fig.2). The magnitude of micro-management was measured with the acceptable number of iterations for information exchange before raising the issue to coordinators (Kristof-Brown and Stevens 2001). A smaller acceptable number of interactions means the coordinators prefer to micro-management. In addition, it has been found that two other sociotechnical factors affect the implications of micro-management: 1) goal congruence, i.e., aligned perceptions of behavioral standards and ranking of management criteria among stakeholders (Thomsen et al. 2005); and 2) task dependence, i.e., the relationships among tasks which determine the order in which activities need to be performed (Jin and Levitt 1996). In the simulation, goal congruence was quantified as a value from 0 to 1, where 1 means the best goal congruence. As for task dependence, a probability was used to determine whether a newly generated task can be processed or not while preceding tasks are ongoing. Monte Carlo simulation was performed to explore the entire uncertainty space. Uniform distributions were used to simulate the changes of micro-management, goal congruence and task dependence.

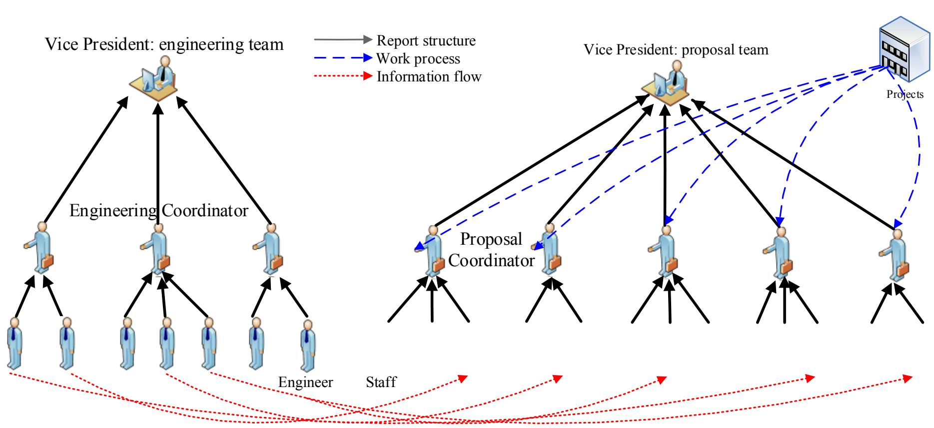

Figure 2. Snapshot of VOICE simulation

Influences of micro-management + goal congruence Fig. 3 illustrates the combined influences of goal congruence and micro-management preference on performance. Micro-management and goal congruence between teams together can alter the shape of performance landscapes. A further ANOVA analysis (Table 2) found that micro-management's influence shows different features under different levels of goal congruence:

- Efficiency: The effects of micro-management on efficiency vary depending on the level of goal congruence. When goals are less congruent between two teams (0.1 and 0.2), micro-management can help improve efficiency. But when goals are highly congruent between two teams (0.8 and 0.9), too much micro-management hurts efficiency.
- Effectiveness: The effect of micro-management on effectiveness also depends on level of goal congruence. When goals are less congruent, such as at a level of 0.1 or 0.2, micro-management improves effectiveness. Otherwise, micro-management sacrifices effectiveness. This indicates that micro-management helps with effectiveness only when goals are incongruent.
- Quality: Result shows that autonomy sacrifices quality in most cases. Micro-management can always help reduce mistakes. However, this is not true when the goals of two teams are highly congruent (e.g., greater than 0.9). In this case, micro-management will slightly increase the chance of committing more mistakes. This indicates that when teams share the same goals, micro-management leads to mistakes.
- Work related pressure: the ANOVA indicates there is a significant relationship (p-value<0.0001) between micro-management and work related pressure at each level of goal congruence: less micro-management or higher level of autonomy for the staff means a higher level of work related pressure.

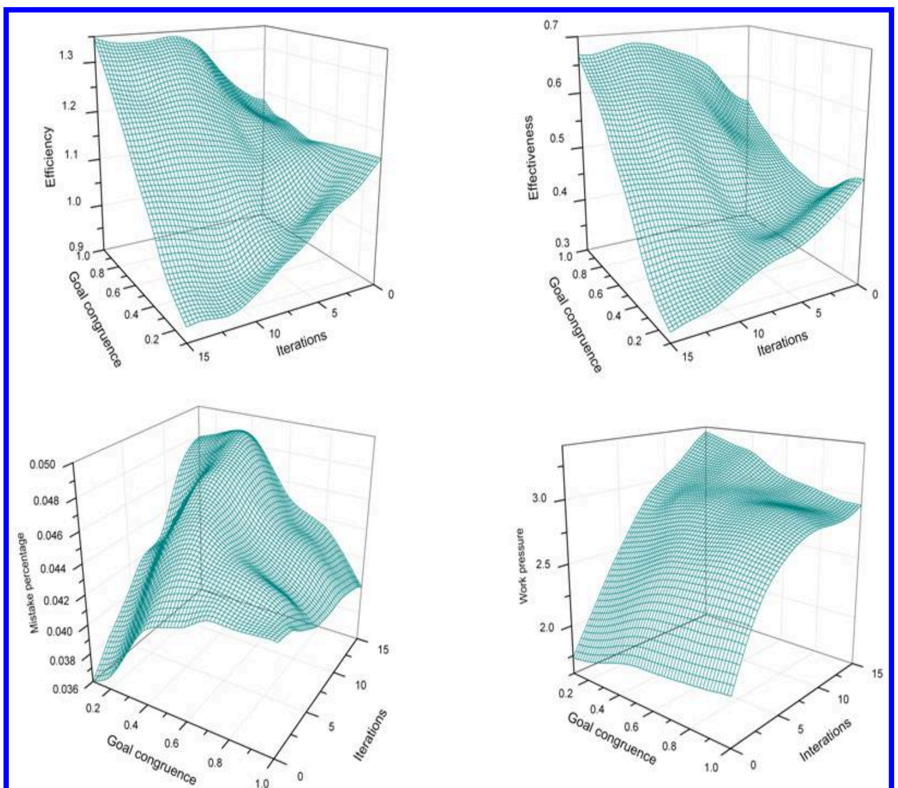

Figure 3. Influences of goal congruence and micro-management

Table 2. p-values of micro-management's influence under levels of goal congruence

Congruence	Efficiency	Effectiveness	Quality	Pressure
0.1	<0.0001*	<0.0001*	<0.0001*	<0.0001*
0.2	0.0002*	<0.0001*	<0.0001*	<0.0001*
0.3	0.0064	<0.0001*	<0.0001*	<0.0001*

0.4	0.3628	<0.0001*	<0.0001*	<0.0001*
0.5	0.3477	<0.0001*	<0.0001*	<0.0001*
0.6	0.479	<0.0001*	0.0134*	<0.0001*
0.7	0.1075	<0.0001*	0.8255	<0.0001*
0.8	0.1533	<0.0001*	0.3698	<0.0001*
0.9	0.0003*	<0.0001*	0.2294	<0.0001*
1.0	0.0024*	<0.0001*	0.0001*	<0.0001*

Influences of micro-management + task dependence The experiment also examined the combined impacts of micro-management and task dependence on performance. Fig.4 demonstrates the results based on 52,800 simulations.

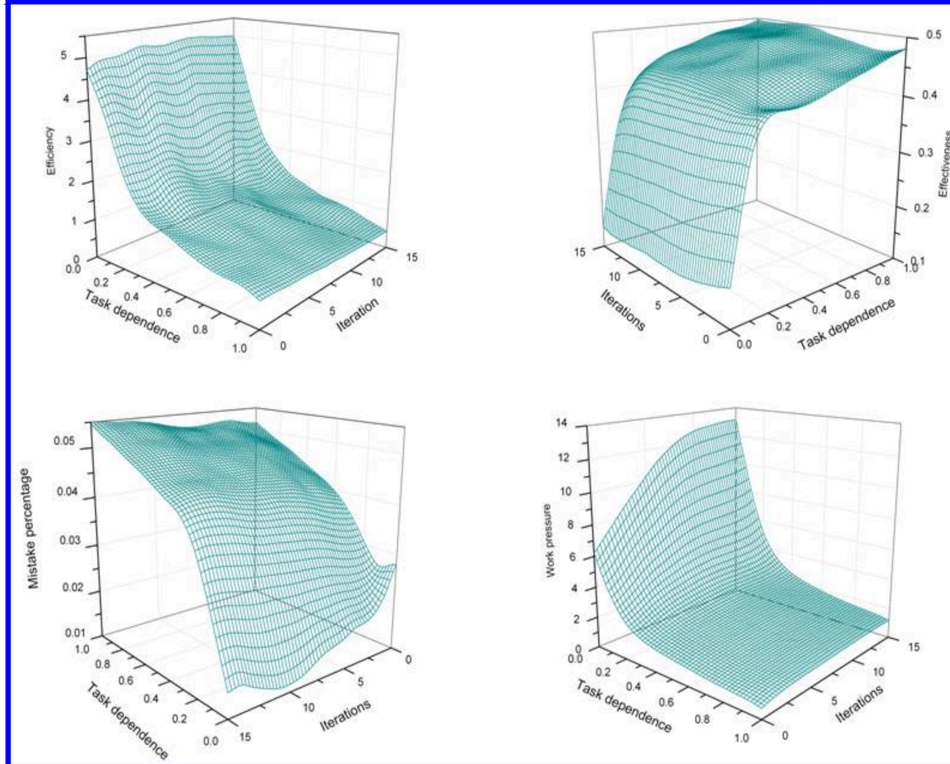

Figure 4. Influences of task dependence and micro-management

An ANOVA revealed the differing effects of micro-management under different levels of task dependence (Table 3).

- Efficiency: the influence of micro-management becomes less noticeable when task dependence is considered. Only when tasks are very independent (task dependence is 0 through 0.2), is micro-management able to improve efficiency; otherwise, it exerts no influence. This indicates that micro-management is beneficial only when tasks are highly dependent.
- Effectiveness: similar to efficiency, the influence of micro-management on the effectiveness of proposal development is not significant when task dependence is considered.
- Quality: autonomy sacrifices quality. When coordinators prefer the autonomy of team members, the team will commit more mistakes. Worth noting, however, is that the opposite trend occurs when task dependence equals 0, and is due to the abnormal data points in the simulation.
- Work pressure: ANOVA does not show a significant relationship between micro-management and work related pressure under most task dependence levels. Only when tasks are highly independent

(dependence is smaller than 0.4) do the results show that micro-management can reduce work related pressure.

Table 3. p-values of micro-management's influence under levels of task dependence

Dependence	Efficiency	Effectiveness	Quality	Pressure
0.0	<0.0001*	<0.0001*	0.003*	<0.0001*
0.1	0.0027	<0.0001*	<0.0001*	<0.0001*
0.2	0.0343	0.0238*	<0.0001*	<0.0001*
0.3	0.0789	0.0862	<0.0001*	0.0253*
0.4	0.1237	0.1658	<0.0001*	0.0448*
0.5	0.3364	0.0822	<0.0001*	0.1864
0.6	0.6238	0.1561	0.0134*	0.3762
0.7	0.1595	0.1231	0.0013*	0.4579
0.8	0.4423	0.0684	0.0002*	0.2688
0.9	0.5864	0.0402*	0.0002*	0.3357
1.0	0.3522	0.0355*	0.0052	0.4238

DISCUSSION AND CONCLUSION

The general organizational science literature always refers to micro-management as a bad practice. However, the implications of adopting micro-management in construction projects remain unclear. This study proposes to investigate the micro-management and its implications in project proposal development from the behavioral perspectives. Unlike previous efforts, it also highlights the importance of considering diverse human behaviors relevant to the proposal development in a comprehensive manner rather than just one or several critical behaviors, as the interactions of various human behaviors set the foundation of understanding complex institutional and behavioral phenomenon. An ABM model, called VOICE, was built to perform a series of simulation experiments on the impacts of micro-management, with the implications of goal congruence and task interdependence. Results indicate that the impacts of micro-management are complex depending on a variety of factors. For example, when team members share congruent goals, micro-management will hurt performance but it will improve performance when team members have incongruent goals. Admittedly, this work is in its infancy. The future work will be focusing on expanding the factors and processes modeled by VOICE to capture a wider range of organizational behaviors. More real data from different companies will be collected in order to define behaviors, work process, and interactions. This will result in more realistic results.

APPENDIX: SUPPLEMENTARY INFORMATION

The behavior rules in VOICE were based on a survey conducted in 2011 and a meta-analysis. For summaries please refer to https://sites.google.com/site/dujresearch/working-papers.

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