ANALYZING CONSTRUCTION PLANNING OF INTERIOR FINISH WORK OF APARTMENT BUILDING BY SIMULATION

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ABSTRACT

The interior finish work needed in apartment buildings has variable points of progress. There are many workers who handle the processes. These processes have variable prerequisite tasks and parallel tasks, so an effort must be made to determine whether a room which workers are sent to is available or not. This is why the process control involved in the interior finishing of apartment building is very difficult. This study is offers a description of the process and a way to handle the complications of constraints through agent based modeling.

INTRODUCTION

BACKGROUND OF THE HOUSING SITUATION IN JAPAN

Recently, construction of apartment buildings, especially high-rise buildings, has increased in Japan. The number of projects has doubled since 2000 and now exceeds 1.3 million. The growth is probably caused by consumer needs and desires to live in cities, as well as the needs of developers to make use of space in cities. Moreover, rehabilitation, renovation and redevelopment of apartments have also contributed to the situation. Since this is the case, the demand for effective management of interior finish work in apartment buildings has increased.

BACKGROUND OF INTERIOR FINISH WORK OF APARTMENT BUILDING

Apartment building work is distributed across two major segments: construction of structure and interior finish work. These efforts result in delays because of conflicting demands on each task. Further, especially in the task of interior finish work, many workers operate in tight spaces causing additional conflicts. There is much research dealing with the process control of construction work because control is very important to the industry. However, most research addresses only construction of the structure. Interior finish work tends to be more complex. For example, workers who build a wall and others who install a bathtub work under different patterns and constraints. The interior workers face different prerequisite and parallel tasks which researchers rarely address. That is why it is difficult to determine the actual efficiency rates associated with interior finish work. It is even more difficult to figure out the efficiency of each worker. But the operational efficiency and production rates are very important. For example, a salaried worker must be paid even if not working, when unfinished prerequisite tasks prevent that worker from accomplishing assigned work. This presents a serious problem to the general contractor. Determining the production rate of each worker is very important to addressing this problem. But the complexity of interior finish work makes it difficult to figure out the actual performance. This study employs a model to calculate the challenges and decision-making processes in an effort to determine a new evaluation index and production rate of each worker.

METHODOLOGY

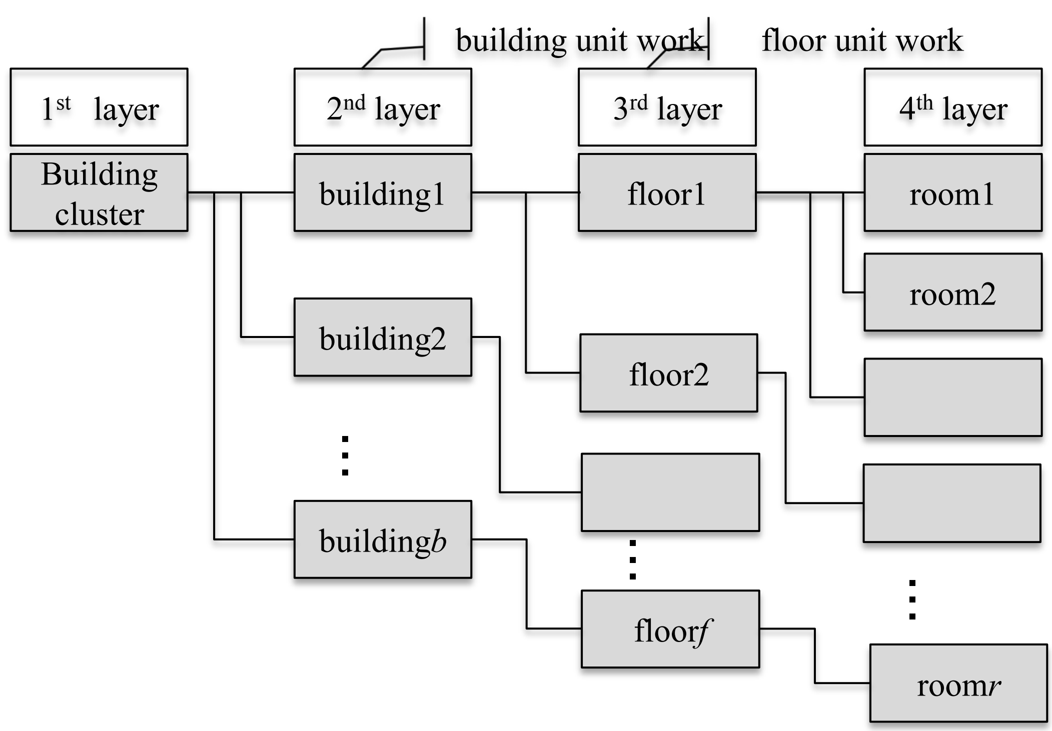
LITERATURE REVIEW

Mine (2000) identified processes associated with construction according to situation-based research. Furthermore, the author identified categories for the relationship between occupations and processes that are advantageous to analyzing the intricate work of multidisciplinary functions. Kadowaki (2003) described the relationship between the efficiency of construction and working unity according to survey research on interior systems work. Nagao (2004) pointed out that work progress suffers due to conflicts between horizontal and vertical efforts. Shide (2009) explored the process analysis and pattern analysis of work progress involving extensive horizontal and vertical tasks, and made clear the relationship between process planning and management. Researchers conclude that the lack of attention to detail causes delays and impacts the relationship between sequential tasks.

METHODOLOGY OF THIS RESEARCH

The research reviewed does not mention decision making and action on the part of each worker, but is limited to work processes. In this study, we use an Agent-Based-Modeling (ABM) approach to discuss the decision making processes and action of each worker. The ABM approach is used to analyze macro-phenomena, while considering micro issues as well. The decision making process and action of each worker represents the micro-phenomena, while macro refers to the ABM approach.

Figure 1
Structure of the workspace



MODEL

OUTLINE OF THE MODEL EXPLANATION

In this section the interior finish work of apartment buildings is modeled with the ABM approach in order to represent elements of the work, working patterns, and the number of preliminary and parallel tasks to be accomplished. By developing a prototype for the process planning of interior finish work, and examining the production performance of workers, we confirm how production is impacted by the number of workers involved in a process. In the following section we summarize the model and define associated terms.

SUMMARY OF MODEL

In ABM, there are agents and places where the agents can move from one spot to the other spot related to a given decision and task. In the interior finish work of apartment buildings, the agents correspond to workers, and the spots or places correspond to work spaces or the office. Each worker goes to work according to his or her assigned tasks, confirms the progress of the construction in their area, and works in that space if possible. When their task is finished, they update their progress and move to the next task and area. They repeat the process until the end of the workday. The work ends for the worker at that particular site when all of the tasks that they specialize in are completed. Thus, the simulation is complete when assigned tasks are completed.

DEFINITION OF WORK SPACE

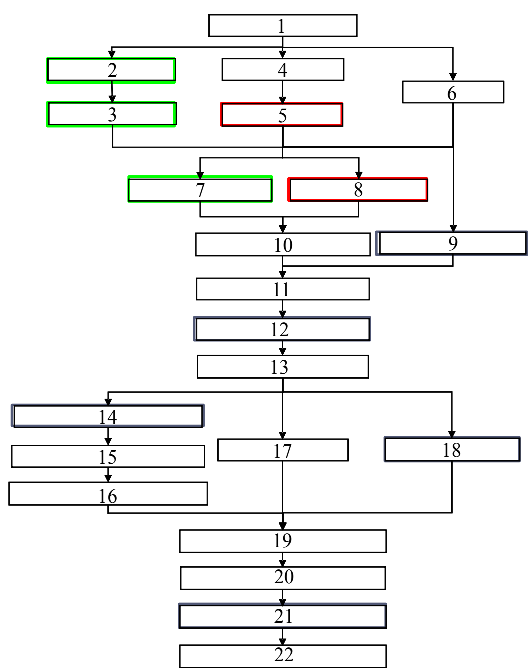
The methodology that treats apartment building constructions as a hierarchical structure is presented by Komatsu (2009), and is employed in the present study. In addition, Ichikawa (2008) researched hierarchical simulated environments. This methodology considers apartment building structure as the first hierarchy, sets of floors as the second, and dwelling units as the third hierarchy. Figure 1 shows the above structure.

The model in previous study, for simplicity, regards the top layer as apartment building structures. However, in this model, the top layer has a higher hierarchy called "buildings cluster," which is more applicable to redevelopment as described earlier above. We create a model that can also support situations where several buildings are constructed at the same time. Each dwelling units has a keyword to represent its status, which is "current work." The dwelling units also have the keyword “Temporary keyword” in order to be able to be adapted to various conditions when we extend the model further. In addition, each dwelling unit has variable list entitled "end process" in order to show the completed process at some point, and "active process" to show the active process. Each dwelling unit is represented by a process and Figure 2 illustrates flow of each process.

Based on interviews of Takenaka Corporation, the Japanese general contractor, this model indicates that the number of workers is 15 and work processes 22. The green, red and gray squares in Figure 2 indicate that there is a job that has multiple processes. These processes become

Figure 2
Flow of each process

no.	jobs	process
1	Carpentry_A	ink out of the base
2	Plumbing Engineering	drainage water pipes
3	Plumbing Engineering	suply Water pipes
4	SP Engineering	SP pipes
5	Duct Engineering	duct including suspension
6	UB Engineering	UB Assembly
7	Plumbing Engineering	UB pipes
8	Duct Engineering	UB duct connecting
9	Electrical Engineering	UB electrical Wiring
10	Floor Engineering	double floor assembly
11	Carpentry_B	base assembly of partition
12	Electrical Engineering	Electrical Wiring of partition
13	Board Engineering	Board of partition
14	Electrical Engineering	kitchen outlet hole
15	Panel Engineering	Installation panel of Kitchin
16	SK Engineering	Installation SK
17	Furniture Enginieering	storage systems
18	Electrical Engineering	Drilling outlet
19	Cross Engineering	Cross-clad
20	Flooring Engineering	Flooring
21	Electrical Engineering	Installation Outlet Covers
22	Takenaka corporation	inspection



a factor that complicates the planning of interior finish work in apartment buildings.

DEFINITION OF FIELD OFFICE

We defined "office" spot as a place where workers make arrangements with each other about the progress of each worksite. The office holds a list of variables (whole room list) to describe the total number of dwelling units and a map of variables (progress table) to record information about the progress of the work of across units.

DEFINITION OF OUT OF WORK

When not in the office or workspace, the worker is defined as being out of work. This spot is assigned a numerical value in order to account for the production rate or lack of production for each worker. More is explained below.

DEFINITION OF WORKER

Workers are assigned key words to represent the current state in which they operate. Assigned values are used to calculate the production or performance of each worker. Further, they have time variables assigned to account for productive time and non-work time. They also account for whether their work is stopped when prerequisite tasks prevent them from accomplishing their task.

The following addresses the actions of workers. Some conditions allow a worker to continue even when prerequisite tasks are not accomplished. After workers go to work, they confirm the status of prerequisite tasks and whether they can complete the work to which they are assigned. If possible, the worker continues the work until it is completed, updates the status of the task with the office, confirms the next assignment with the office and continues.

Another issue is that workers face a problem when more than one person is assigned to a particular workspace. These constraints mean that workers cannot accomplish their task when there are other workers in the same place. Therefore, workers try to confirm whether there are already other workers operating in his or her workspace prior to going to their assigned place. If confirmation is possible, then the worker can avoid wasting productive time either in transit or while waiting for others to finish prerequisite tasks. So, it becomes important for workers to go to the office and update their progress and status. Every workers repeats this cycle until the end of their working hours. When workers are not finished at the end of the day, remaining work is left undone in a particular room. Every worker repeats this series of actions and decisions until all work is completed in all the rooms for which they are responsible.

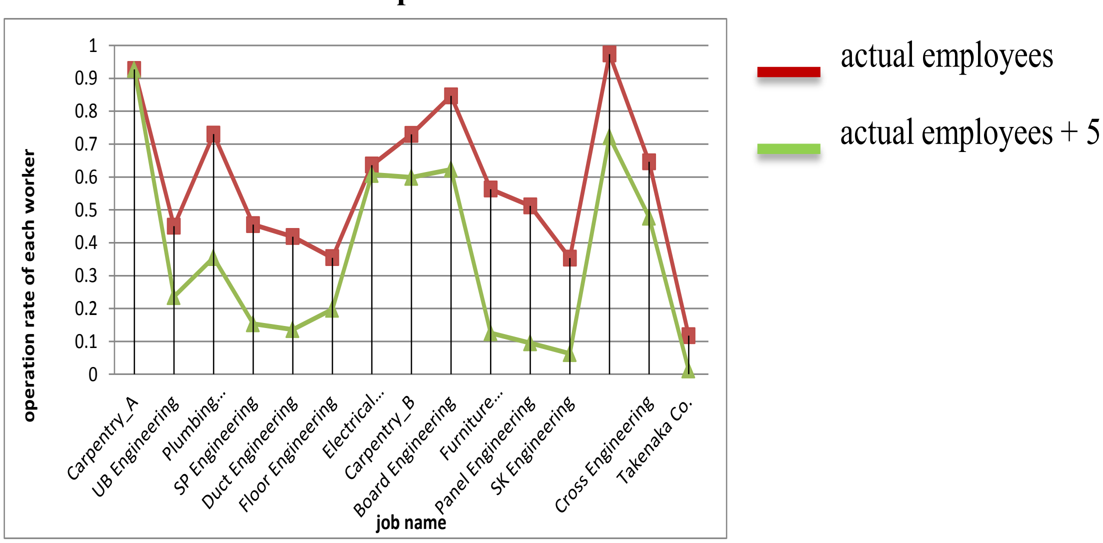
DEFINITION OF EVALUATION INDEX (OPERATION RATE OF EACH WORKER)

In this study, the goal is to define an evaluation index for the production or operating rate of each worker. The index OR (operating rate of each worker) can be represented in the following calculations:

F_{time}: After work hours Status
OFF_{time}: State the time of departure
PP_{time}: Time bound by state
ROt_{ime}: Time actually working condition
All_{time}: All simulation time
OR: The actual work rate
Then

$$PP_{time} = ALL_{time} - (NN_{time} + F_{time})$$

Figure 3
Operation rate of each worker



$$OR = \frac{RO_{time}}{PP_{time}}$$

This calculation procedure is very simple, but in a top-down approach is not possible to express it. This index cannot be represented without ABM methodology.

SIMULATION

ASSUMPTIONS

Model assumptions are as follows.

1. In this model, the simulation time lapse is six-minute intervals.
2. The model, starting at 0:00 simulates and calculates until the termination criteria are met.
3. 24:00 is close of day, as is the next day.

CONSTRAINTS

To simulate this model, we define some constraints on the interior finish work of apartment buildings.

1. Constraints about the number of human resources. There is no constraint on the number of human resources. If a contractor invests a lot of human resources, they will shorten the work period, which is best. However, because of prerequisite work, even with increased workers, they cannot shorten the work period linearly. So, above a certain number, the investment of human resources has no effect.
2. Constraints on work period. Works periods have strict constraints. The workers who operate first can complete 1 floor in 6 days. As we mentioned above, the construction of apartment buildings is distributed across two major tasks, construction of the structure and the interior finish work. Interior finish work can begin before total completion of the structure, but interior finish work cannot get ahead of construction of the structure, even if 1 floor is completed in 6 days. So, the efforts to complete interior finish work must account for the pace of the construction of the structure.

SCENARIO SETUP

We create a prototype model based upon the concept of this research with the aim of understanding the production rate of workers who encounter various problems faced in actual practice. The goal is to be able to analyze efficient worker productivity and wages given the varied operating conditions and worker performance patterns. We used Simulation language, SOARS (Ichikawa, 2007), which is designed for social simulation to construct the prototype model. This prototype model offers a basic framework, which allows it to be easily modified for future use. The Simulation language does not require great programing skill and the language has versatility. For example, the number of human resources, floors and rooms of the building and room type can be changed by importing a CSV file. In this model we assume apartment buildings have the 20 floors and 16 rooms per floor. Table 1 illustrates the parameters of this model and the actual numbers associated with each process. The numbers and parameters were again through interviews at Takenaka Corporation.

Table 1
Parameters set up and
Actual number of each process

parameter	explanation	value
b	the numbe	2
f	the numbe	10
room	the numbe	320
type	room type	2LDK
n	the numbe	22
m	the numbe	15
st	starting tim	Am8:00
ft	finishing tir	Pm5:00
ot	over time v	0

SIMULATION RESULTS

In this study, productivity is impacted by regarding wages as an investment in workers. In turn, this increase in human resources and its impact is measured by the effect on the prayer to the rate of workers. Figure 3 illustrates the worker's productivity rate for each task. Thus, we can simulate the actual number of employees to use and subsequent increases in workers, also accounting for the impact of the completion or non-completion of prerequisite tasks upon each worker's productivity.

The red line represents the simulation according to the number of actual employees, while the green line represents an increase of 5 workers for each job, while noting that Carpenter A must complete the work first.

EXPERIMENT AND RESULT

We did an experiment with the above index. We increased and decreased the number of workers on each job. We measured the effect on job productivity and other factors in the experiment. The results are grouped into the the following four patterns.

1. Increases and decreases in the number of workers which impact workers and other jobs.

2. Increases and decreases in the number of workers which impact workers, but not other jobs.
3. Increases and decreases in the number of workers which do not impact workers, but impact other jobs.
4. Increases and decreases in the number of workers which do not impact workers and do not impact other jobs.

The number of workers in these patterns (1 and 3) need to be changed, because they affect other jobs. This experiment points out the possibility of causing a negative impact upon sequential drop processes by increasing the number of workers. Interviews with Takenaka Corporation personnel, who have used other indices and work measures for many years, help to confirm our conclusions.

CONCLUSION AND FUTURE WORK

This paper makes it possible to know how to change the production rate of each worker by increasing the number of workers, while accounting for impacts on production caused by prerequisite tasks. This new index points out the possibility inaccuracies in processes that have been in use for decades. Also, in this new index the production rate of actual work per worker is thought to become very important in the consideration of various problems in the future. For example, if someone plans to change the number of human resources in use, they can choose a more effective plan by considering this new index and the actual impact upon the production rate of workers. In the future, expanding the versatility of this model might be challenging when other factors must be considered, such as workers helping each other to ensure that employment opportunities are increased. In addition, using the index in this study, we believe that it is possible to consider the impact on construction when cross-trained workers are employed and how those workers would align with the issues presented by prerequisite tasks and particular rooms to be completed.

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