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Nursing Business Modeling with UML: From Time and Motion Study to Business Modeling

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1. Introduction

A nurse is an autonomous, decentralized worker who recognizes goals, his or her environment, the conditions and actions of patients and other staff members, and determines his or her own actions. Put another way, the nurse makes decisions flexibly in the midst of uncertainty. Because of this, nursing work differs from individual nurse to nurse, and understanding this process theoretically is considered to be difficult.
Concerning nursing work analysis, research has been done on task load (time required for tasks). However, there has been scant academic research on work processes in nursing compared with research that has accumulated in other industrial fields, including research on structuralizing work, i.e., defining and visualizing work processes. To improve work processes, it is necessary to understand and clarify work as a chain of theoretically related activities.
Thus in this study, using time and motion study techniques, a method used to measure jobs, we clarify the structure of the work of transporting patients by nurses. We also attempt to visualize it. We use objected-oriented modeling to express the operation visually.

2. From time and motion study to business modeling

Time and motion study is a method that actually measures the movements of a particular person. Its results can be applied not only to measuring the work load of nurses (Van de Werf et al., 2009; Were et al., 2008;Hendrich et al.,2008) and analyzing the workflow(Tang et al., 2007), they can also be used as basic data for task scheduling(Yokouchi et al., 2005) and efficient arrangement of personnel. In addition, the results are being used as indicators to evaluate changes in a hospital brought about by systems deployed (Yen et al., 2009), such as an electronic medical record (EMR) system. Thus many time and motion studies of hospitals have been conducted both within Japan and without.
Specifically, a time and motion study is defined as a study that records the time of occurrences of tasks through continuous observation. A type of measuring technique similar

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to the time study is work sampling, which seeks to comprehend a job by sampling its conditions at predetermined time intervals. Work sampling cannot comprehend a job in its entirety, but it lessens the burden on the measurer. It also makes it possible for the worker himself or herself to record time. In contrast, a time and motion study comprehends the job in its entirety, but the burden on the measurer is great. The differences in results between the two methods have been observed to be large for jobs in which there were few events(Finkler et al., 1993). Currently, the results that come from measuring a job through continuous time and motion observation are said to be the gold standard.

While the breadth of research that utilize measurement results from time and motion studies encompasses all nursing work, individual studies have been limited to examining the amount of work for individual caring assignments, such as cleaning a patient, feeding a patient, and taking care of a patient's toilet needs. There have been especially few studies that evaluate the work amount of a job by focusing on the job and clarifying its work process. While not on concerned with nursing work, the only such study conducted so far in the medical field was visualizing and understanding the amount of work involved in the process of registering cancer patients by Shiki et al. (Shiki et al., 2009). They proposed the method of "time-process study," a method to visualize tasks by adding time information to the process. However, because both the process and amount of work were estimated through interviews, the results can be said to be lacking in objectivity. Thus our study uses the time and motion study method, which actually measures a task. We focus on the job of transporting patients and clarifying its process. We also study the possibility of a method to visualize the work process using the clarified process and time information.

Transporting patients is an operation that is often performed outside hospital wards. It is both physically and mentally demanding of nurses. This job should also be scrutinized because it reduces the number of nursing staff inside the wards, as nurses go outside the wards in order to safely transport patients.

3. Methods

3.1 Study setting

We carried out a time and motion study of nursing work related to transporting patients in four hospital wards of a cardiovascular treatment facility. We tracked our subjects, who were nurses, nursing assistants, and medical clerks, from the time of the start of a task until its end, and recorded the task actions. The record of a task action included the content of the action, the time of its start and end, the person who was the target of the action, and the location of the action. The four wards of the treatment facility consisted of the cardiac failure ward, arrhythmia ward, cardiomyopathy/pulmonary hypertension ward, and cerebral vascular and metabolism ward. The destinations of patient transport included exam rooms for CT, X-ray, MRI, echocardiography, respiratory function testing, cardiac rehabilitation, neurological rehabilitation, cardiac catheterization investigation, and dialysis.

3.2 Business modeling with UML

From the time and motion study records we obtained, we created a use case diagram and activity diagram. Use case diagrams and activity diagrams are types of diagrams created using Unified Modeling Language (UML). UML is the de facto standard objected-oriented modeling language, and was developed for software development. In recent years,

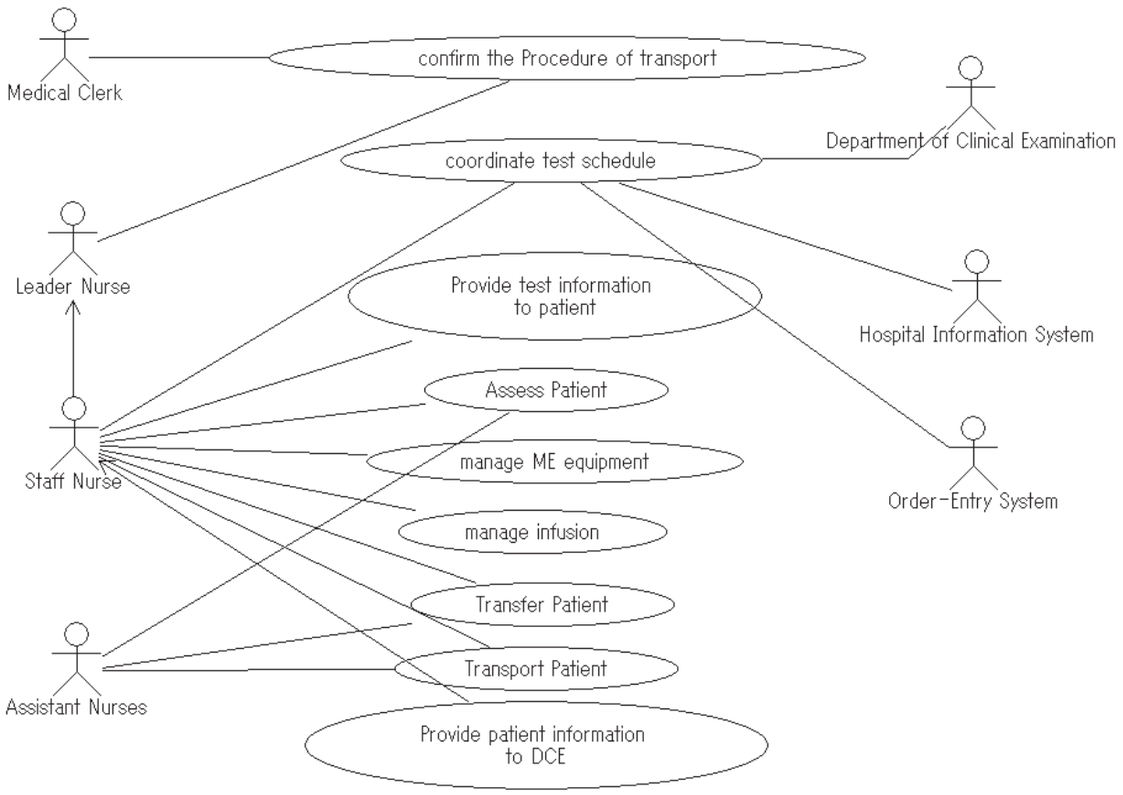

Fig. 1. Functional diagram-patient transports system.

however, its use for business modeling has been suggested (Eriksson and Penker, 2000). The reason is that the structure of a job can considered oriented-oriented in nature. The content of a job can be treated as exchanges of messages between objects, such as materials and users. Thus UML as a descriptive method can allow one to intuitively understand the job. In this study, we elucidated the functional aspect of the operation of transporting patients. We also used an activity diagram to visualize the work process of transporting patients. Finally, we discussed the work load and its time efficiency by adding time information to the activity diagram. This study was approved by the ethics committee of the hospital we studied.

4. Results

From the time and motion study, we observed and recorded 213 jobs of transferring patients. Overall, the number patient transfer assignments recorded was 3,775. Of these records, 387 records were not jobs related to transporting patients, so they were removed from our analysis.

A use case diagram extracted from the results of the time and motion study is shown in Figure 1. There were seven types of actors involving in transporting patients: nurses, head nurses, medical clerks, nursing assistants, the central medical examination department, the order entry system, and the hospital information system. The nurses were divided into two groups: head nurses, who had the responsibility of being in charge of nursing duties, and staff nurses, who received patients and provided care for them. The head nurse and the

medical clerk received communication about the transport of a patient, and confirmed the predetermined method of transport care. In addition, the head nurse made adjustments such as changing the transport personnel and finding appropriate personnel. Of the tasks related to transport care, the nurse and nursing assistant handled tasks that had direct bearing on the patient. In the hospital of this study, patients undergoing oxygen therapy, patients being monitored by EKG, and patients undergoing transfusion were the responsibility of nurses, not nursing assistants.

Task	TOT	Frequency	Median	Range
T01 Coordinate time for examination	0:33:27	28	58	(5-273)
T02 Confirm schedule of examination	0:05:24	10	29	(4-100)
T03 Accept call for examination	0:31:30	45	34	(1-324)
T04 Look for patient record	0:04:32	11	18	(2-64)
T05 Check bed rest level	0:09:11	10	36	(6-186)
T06 Identify care-giver	0:00:58	3	21	(4-32)
T07 Prepare map	0:08:27	20	23	(3-70)
T08 Prepare patient consultation card	0:14:37	31	18	(1-108)
T09 Prepare patient record	0:28:41	42	31	(5-187)
T10 Find care-giver	0:01:59	3	42	(16-60)
T11 Find patient	0:07:33	11	17	(4-116)
T12 Wait for care-giver	0:00:21	1	21	(21-21)
T13 Relay examination information to patient	0:29:55	43	34	(1-144)
T14 Hand necessary materials to patient	0:00:21	3	6	(2-13)
T15 Change care-giver assignment	0:00:37	1	37	(36-36)
T16 Relay exam information to nurse	0:26:48	38	21	(1-384)
T17 Prepare film	0:00:44	2	22	(15-29)
T18 Prepare materials to be brought	0:04:02	3	38	(6-198)
T19 Prepare transport care equipment	0:22:38	46	20	(1-139)
T20 Carry transport care equipment	0:21:27	40	26	(1-88)
T21 Assess situation	0:24:48	17	26	(2-382)
T22 Confirm patient name	0:02:45	10	16	(6-30)
T23 Prepare to move ME devices	0:13:50	19	31	(7-237)
T24 Prepare to move medical supplies	0:16:43	23	42	(2-117)
T25 Assist in excretion	0:05:16	5	52	(10-152)
T26 Assist in changing of clothes	0:12:35	19	25	(10-127)
T27 Prepare for transfer	0:10:22	13	29	(5-199)
T28 Carry patient	1:46:59	83	43	(3-707)
T29 Transport patient	9:15:49	109	292	(1-866)
T30 Go through reception procedures	0:08:56	34	9	(1-90)
T31 Hand-over patient	0:01:55	8	13	(2-34)
T32 Hand-over necessary supplies	0:10:31	30	15	(1-89)
T33 Relay information	0:33:09	31	63	(3-156)
T34 Prepare for examination	0:27:16	26	32	(1-370)
T35 Assist in examination	0:42:01	41	28	(6-255)
T36 Standby at destination	1:57:19	35	92	(1-1612)
T37 Receive patient	0:06:37	7	20	(6-208)

Task	TOT	Frequency	Median	Range
T38 Reattach ME devices	0:41:25	18	82	(6-766)
T39 Reattach medical supplies	0:21:23	14	69	(2-396)
T40 Secure consultation card	0:04:35	23	9	(1-44)
T41 Secure patient record	0:23:02	30	19	(1-560)
T42 Clear away film	0:00:28	4	5	(3-16)
T43 Clear away transport care equipment	0:25:52	40	34	(2-115)
T44 Clear away map	0:01:54	5	11	(1-78)
T45 Finish clean up	0:13:24	15	33	(1-159)
T46 Record the transfer	0:11:10	11	32	(3-247)
M Move	4:36:03	119	95	(2-1068)

TOT: time on task.

Table 1. Identified tasks and their descriptive statistics.

The dynamic aspect of transporting patients is shown as an activity diagram (see Figure 2). The head nurse, who is in charge of communication in the hospital ward, and the medical clerk receive a call for a patient from the central medical examination department. They confirm the bed rest level of the patient from his or her chart. If the patient can walk outside the ward by himself or herself (self-reliant), the person in charge of communication prepares the chart, the patient's exam ticket, and the map to the exam room. He or she searches for the patient, relays the call for examination to the patient, and hands over necessary items. If the bed rest level is escort (transport in a wheelchair) or litter care (transport on a stretcher), the person in charge of communication searches for the transport personnel and hands over the exam call. The transport personnel prepare the patient's chart, the exam ticket, and the instrument for transport care such as a wheelchair or stretcher, and move to the patient's location. They relay the exam call to the patient, and assess the patient's conditions to determine if transport is possible. If the transport personnel determine that the patient can be transported, he/she/they prepare oxygen or transfusion devices for transport, and perform excrement care and assist the patient in changing clothes. Next, the transport personnel move the patient from the bed to the transport instrument, and transport the patient to the exam room. After the patient arrives in the examination room, the transport personnel notify the exam receptionist of the patient's arrival, hand over the patient, and hand over items brought along, such as the patient chart and the exam ticket. If the exam takes only a short time, e.g. in the case of an x-ray exam, the transport personnel wait in the exam room, assist with preparing the patient for examination, and assists in the examination. If the exam takes a longer period of time, the transport personnel return to the hospital ward and perform other tasks. When communication comes from the examination room, the transport personnel receive the message and move to the exam room. After the exam has completed, the transport personnel receive the call from the patient, transfer the patient to the transport instrument, transport him or her back to the ward, and again move him or her to the hospital bed. The transport personnel prepare medical electronic equipment and medical devices attached to the patient so that subsistence in bed is possible. After assessing the patient's conditions, the transport personnel puts away the items brought along, such as the exam ticket and the patient chart, and record the transport. As shown in the activity diagram, we clarified that the process of transporting a patient was composed of 47 tasks.

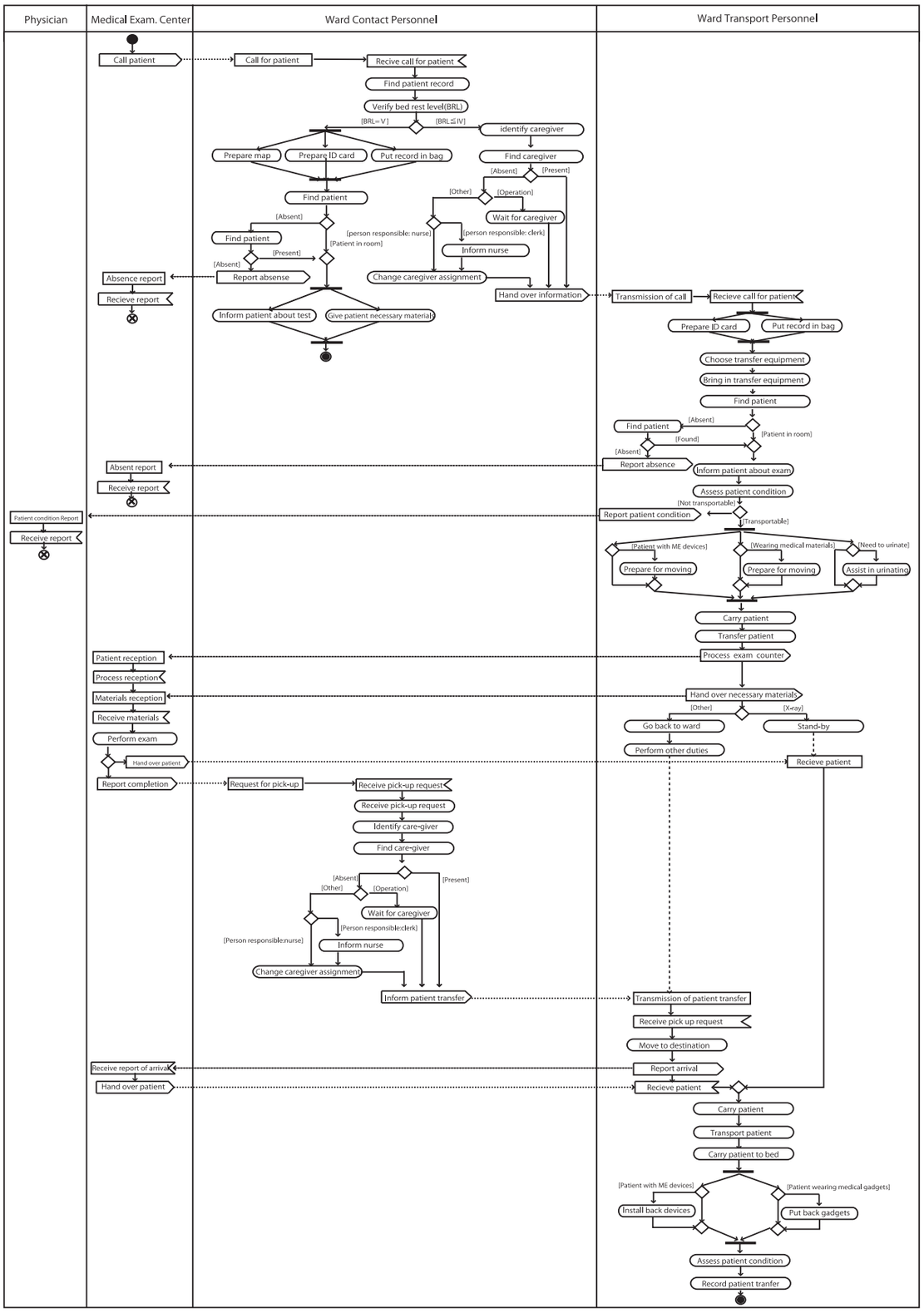

Fig. 2. Dynamic diagram-patient transports.

Table 1 shows the total time on task during a day in the four wards for each of the 47 tasks shown in the activity diagram. Also shown are the number of occurrences of each task, the median value, and the range. The task that took up the most total time was "T29 Transporting patient" (9:15:49). It took about 5 minutes on average for the nurse(s) to transport a patient. Of the 213 patient transport jobs observed, 109 actually involved transporting the patient. Patient transport jobs that did not involve transport were only those to support self-reliant patients and to adjust the scheduled time of exams. After T29, the task that took the most time was "T36 Standing by at the destination" (1:57:19), followed by "T28 Transferring the patient" (1:46:59). On the other hand, there were few occurrences of tasks related to searching for or changing transport personnel, such as "T06 Identifying care provider," "T12 Waiting for care provider," and "T15 Changing care provider." Comparing the coefficient of variance, we found that the coefficient of variance for "T41 Putting patient chart away," "T16 Conveying exam information to nurse," "T36 Standing by at destination," and "T21 Assessing conditions" was high. On the other hand, the coefficient of variance of "T29 Transporting patient" and "T43 Putting instruments for transport care" was relatively low.

The time on task for each type of task is shown in Table 2. Direct tasks are those that deal directly with the patient. Indirect tasks are tasks carried out without direct contact with the patient, including preparatory tasks for direct tasks and cleaning tasks. Direct tasks, which involve transporting the patient, made up about 60 percent of all tasks, and indirect tasks made up 14 percent of all tasks.

Task category	No. of task	Time on Task	(%)
Indirect care	21	3:56:23	(14.1)
Direct care	21	16:08:27	(58.0)
Communication	2	0:59:57	(3.5)
Waiting	1	1:57:19	(7.0)
Record	1	0:11:10	(0.6)
Move	1	4:36:03	(16.5)
Total	47	27:49:19	(100.0)

Table 2. Time on task by each task category.

5. Discussion

First, we clarified the location and roles of persons in charge of tasks by making use of time and motion study data to visualize the object-oriented work process. From a functional point of view, the main persons in charge of the job of transporting patients were nurses. However, we understood that medical clerks participated in coordinating communication and that nursing assistants participated in transporting patients who did not need custody

or attachment of medical electronic or transfusion devices. We understood that while medical clerks received communication about exams and confirmed the method of transport care on the patient chart, they did not have privilege to change the transport personnel or delegate the task, so they turned the task over to lead nurses. Furthermore, in the case of self-reliant patients, the person in charge of communication in a ward had the responsibility of transmitting the exam information to the patient regardless of whether he or she was a medical clerk or nurse. Furthermore, in the case of patients who needed wheelchair or stretcher transport, the person in charge of communication had the responsibility of sending information about the exam call to the transport personnel after receiving the communication about the exam. Our study showed that if the person in charge of communication was a medical clerk, he or she turned the task over the head nurse, because he or she did not have the privilege to change the care provider. The task that took the most time in this process was "Conveying exam information to the patient," followed by "Preparing patient chart" and "Preparing exam ticket." Use of the exam ticket was limited to outpatient exams of hospitalized patients and during the medical exam, so the repositories of the tickets were fixed. In contrast, because patient charts were used for a variety of purposes by physicians, nurses, medical clerks, and many other hospital employees, search for the charts took place, and the time required to prepare the charts grew longer. After information was conveyed to the transport personnel by the person in charge of communication, the transport personnel handled all responsibilities, including the final task of recording the transport.

Second, we understood the divergence between the work process specified in the hospital procedures manual and the actual work process. The manual used in the hospital of our study did not specify tasks such as "Searching for the patient," "Searching for the transport personnel," "Changing the transport personnel," "Preparing the exam (in the exam room)," and "Assisting in the exam." This reason is that the work procedures manual contains standard procedures. Irregular events and redundant tasks that should be kept in mind were not included. Also, the procedures manual was written to describe work procedures for individual nurses, so the location and role of workers described above were not clarified.

Third, from the work process diagram based on actual work records collected by this study and by adding time information to the process, we understood the efficiency with which tasks were carried out. By understanding the time used for each task and the variability of time, we clarified the time element that makes up the care of transporting patients. In the future, we seek to understand in detail how time on task changes depending on constraints.

Fourth, our study suggests that the data can be used for risk analysis. Our study extracted 47 tasks that made up the transport of patients, and listed their sequential order from time study records. Through our study, we clarified the input and output of each task, as well as the frequency of irregular events. Irregular events such as "Searching for the patient" and "Searching for the nurse" can be considered risks recorded by this study that prevent the work goal from being achieved. Although not carried out in this study, each task can be scrutinized to clarify factors that hinder each of their output. Doing this can draw out the risks associated with the work of transporting the patient, and produce discussions about concentrating risks and avoiding risks.

6. Future outlook

In this study, the structure of the work of transporting patients was visualized. The study suggests that the work of transporting patients has great differences in the objects, the process, and time efficiency depending on the conditions of the patients, type of exam, and occurrence of the work. Also, because many work occurrences were irregular and required quick responses, we learned that nurses must make adjustments with other tasks while at the same time accomplishing the task of transporting patients.

This study showed the usefulness of time and motion study for clarifying not only work load but also work structure and work processes. In the future, we seek to confirm the applicability of this study by conducting similar studies based on other jobs and records of jobs in several other facilities.

7. Acknowledgment

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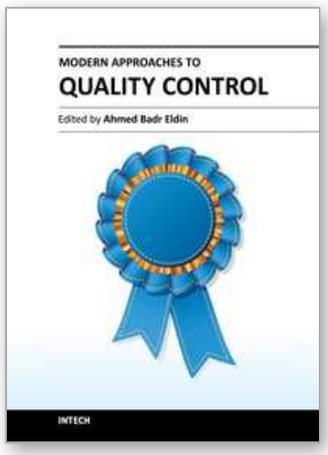

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