TRANSFORMATION OF INFORMATION FLOWS AND WORK PROCESSES FOR FIELD SUPERINTENDENTS

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ABSTRACT: *This paper addresses field information flows and work processes of one of America's largest residential homebuilders. This residential contractor currently uses a combination of; 1) web based scheduling, allowing subcontractor to self schedule, 2) an e-order process for material procurement, which allows field superintendents to make simultaneously orders for multiple houses, 3) web based subcontractor payment authorization and 4) a mobile phone network internal to subdivision contractors to help deliver a portion of the parent company's 50,000 houses a year. The objective of the research investigation is to understand which real time information in which format, will best assist construction supervision.*

The information mapping process for a sample of residential field superintendents is documented. Differences between the corporate workflow and information system and the system actually used by the field superintendents are highlighted. These differences guided the development of a revised information system and workflow that better serves the needs of the field superintendents. The basic field communications mechanisms and connections to the corporate database are documented.

Observed ready, set, go points that connect information processes to field task initiation are also, identified within the paper. The reconfiguration of these established trigger points is addressed and identifiable information gaps are discussed. The information exchange techniques to ultimately self-activate work processes are also explored and presented.

1. WORKFLOW PRACTICES OVERVIEW

A division of one of America's largest homebuilders has embarked on a business transformation that includes the use of web based project management techniques to streamline field supervision's on-site project management. One aspect of construction deals with the communication link between the customer, the construction manager/superintendent, and the subcontractors and suppliers. Christofferson notes that a staffer with the National Association of Home Builders estimates there to be approximately 29,000 items to account for during construction of a new home. (Christofferson,

1999) These 29,000 items must all be accounted either physically and/or mentally during the approximately 90 day schedule of most production builders.

An investigation into the consistency and adequacy of this home builder's existing information exchange mechanisms was undertaken in an effort to transform and extend current business practices into flexible and efficient information exchanges. The objective is to understand which real time information in which format, will best assist construction supervisors and facilitate efficient supervision. Once realized, these mechanisms can be implemented in the transformation. Current field practices of this builder rely on first order paper list, with later manual categorization for subsequent actions. This data is then entered into a desktop web based project management system for information exchange.

The parent company of this home builder is responsible for closing over 50,000 homes per year and has developed a well tested and successful approach toward closing a house. Although all work is subcontracted, not all divisions use a web assisted management system. The baseline e-project management system is initiated by a house information sheet, and is supported by three basic modules, 1) web based scheduling, 2) e-order material procurement, and 3) web based subcontractor payment authorization. The e-project management tools are supplemented by field communications through a networked wireless phone system.

1.1 House Information Sheets

The house information sheet is a one to two page document created for each home. This sheet lists customer information, house information and customer selections for the house. For example, the document includes information such as the community, address, lot number, unit type, customer name, permit, tax number, interior/exterior packages, colour selections, all changes and/or special options. The document forms the basic information database and is dynamically linked to a specific house for a specific owner. A house information sheet is printed and physically posted in each house during construction.

1.2 Web Based Scheduling

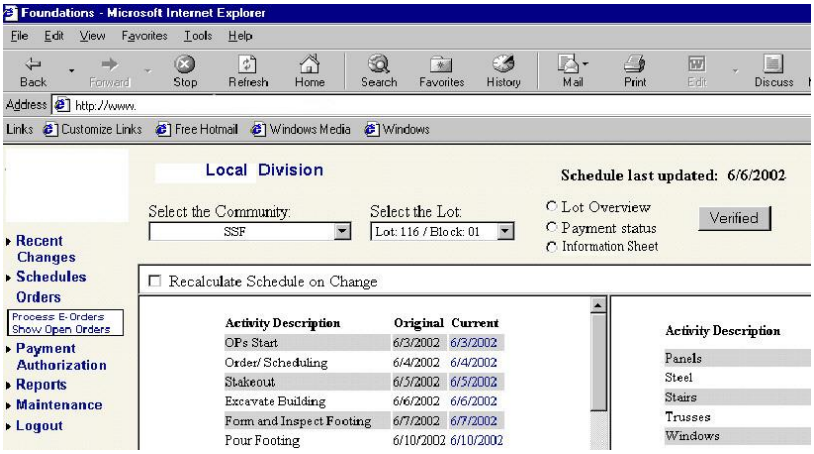

Figure 1 - Screen image - Web based schedule

The online web schedule, Figure 1, is the tool this builder uses to schedule construction activities for each house. There are eighty nine activities and each is given a one-day duration. There is a separate column that tracks the superintendent's schedule versus the 89 day schedule. When the superintendent inputs the start date the schedule is automatically generated. The superintendent updates his or her schedule using drop down menus for quick and easy date selection. Once within the web based

system, superintendents can make schedule updates, electronically order materials, and make subcontractor payment authorizations.

Schedule print outs are periodically generated for each house under construction. This is done by the superintendent for an entire schedule and for two week time periods. The subcontractors and suppliers receive a custom schedule of their work based on the web schedule. The subcontractor's schedule is accessible online through a web browser and contains the lot numbers, activity descriptions, their schedule dates, and date the schedule was last updated. Up to date scheduling is allowing the subcontractors to preplan their work schedule without daily site visits.

1.3 e-Order Material Procurement

The electronic ordering screen, Figure 2, is another feature of the web management schedule that allows the builder's superintendents to electronically order ("E-order") certain materials linked as activities on the schedule. The order, once processed is automatically e-mailed to the subcontractor and contains the items needed, the date needed and the lot number. Within this e-mail is a direct web link (URL) to the house information sheets for the material suppliers use. A superintendent can place multiple house orders while in the same online session.

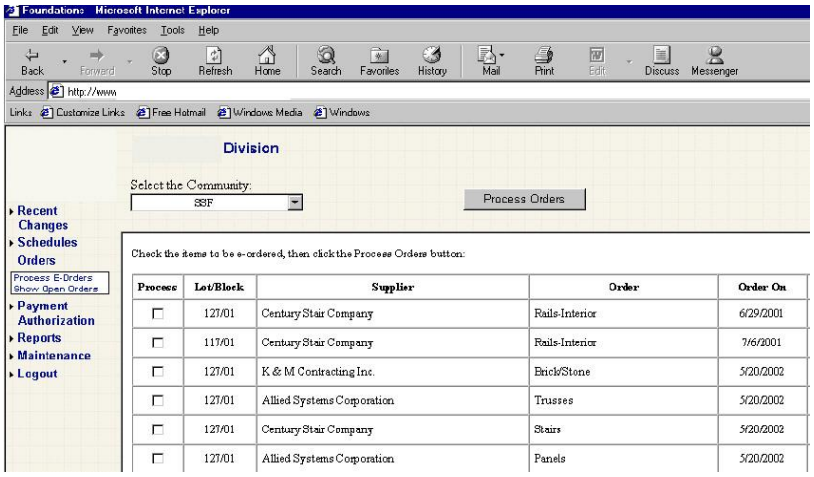

Figure 2 - Screen image - Web based e-Order

1.4 Web based Subcontractor Payment Authorization

A web based subcontractor payment authorization feature allows the builder's superintendents to authorize payment for completed activities. The payment authorization screen is similar in format to the previous two screens and contains the lot number, supplier, account code, and work task. The superintendent clicks the items to be paid and then clicks the "Process Payment" button. Upon automated receipt of this authorization, the accounting department will pay the subcontractor.

1.5 Mobile Phone Network

The mobile phone network is a commercial wireless network that allows all subcontractors to be enrolled within the network and uses single button "press to talk" access. This fills the gap in communication allowing instantaneous contact among superintendents and subcontractors.

2. CONSTRUCTION INFORMATION

Betts, et. al. states that construction needs to change as a result of a dissatisfied client base being offered undifferentiated products and services (Betts et. al, 1999). Residential construction is highly susceptible to this condition and thus presents a unique solution set as vendor-builders in meeting this challenge through re-engineered business practices. Typically residential vendor-builders construct many houses simultaneously, under separate owner-builder contracts, using the same subcontractors, with repetitive work that combines cross function duties in field supervision. Product mix, as in manufacturing, changes frequently, turning over every 12-18 months.

Re-engineered business practice goes by many names, business process redesign, information transformation, and business process re-engineering are just a few. Each intends to use a process oriented solution to alter business practices. Betts, et. al. have coined the term "business process redesign" (BPR) as a means to simplify various theories using a common term (Betts et. al, 1999). Within the domain of construction much work has been done on categorizing information flows and work processes for the natural transformation to an Information Technology (IT) assisted domain.

Tenah provides several early studies on the information flow and processing requirements of large to medium non-residential construction companies. His work identifies five major groups of information requirements and categorizes these into functional information needs and notes the concept of simultaneous information processing (Tenah, 1984, 1986). Kagioglou, Cooper and Aouad have recently completed long term research to re-engineer the design and construction process within the UK. Their focus was targeted at a process-driven model primarily based on "best practice" manufacturing in new product development. Their work concludes that successful implementation of organizational change, particularly in a vendor-builder environment, will result from a process-oriented emphasis (Kagioglou et.al. 1999).

2.1 Residential Construction Information

Residential supervision crosses the three simple categories of "Technical Information", "Commercial Information" and "Management and Control Information, as summarized for construction in the 1995 UK Construct IT report (DoE-UK, 1995). US residential construction is characterized by large "production vendor-builders" that use common subcontractors on all projects (houses), contracted through "models based" purchase orders. Within this context the predominant management and supervision tasks are all coordinated on-site by superintendents once the house is initiated for construction. This creates a captive subcontractor trades group operating on sequential one day duration construction tasks. One day task are critical and without built in slack any delay ultimately delays completion.

Christofferson has identified the communication of scope changes as a dominant obstacle to residential construction progress. As a result he has developed a "specification information flow" software model. This flow model and software application is targeted at mitigating this communication deficiency (Christofferson, 1999). Christofferson's conclusions on communication deficiencies are consistent with a breakdown that eventuates when changes are implemented into a "models based" purchase order production system. For efficient production building to be successful, timely access to information updates is essential. Thus it is imperative that the right information be available, in the right format, at the right time, and at the point of need, hence analysis directed at building process redesign (BPR) not construction task will effect major change in residential construction.

3. RESEARCH APPROACH

To effect transformation a baseline corporate work process was first defined, and then charted using an unstructured process mapping technique. This baseline was representative of the corporate scheduling strategy defined in previous work (Wakefield et. al. 2001). In conjunction with the builder, three superintendents were selected to participate in this study. Selection was based on personnel availability, work-in-progress and early adoption of the current web management system.

The superintendents were each responsible for different subdivisions at geographical different sites under differing municipal regulations. Superintendent 1 was responsible for a subdivision of 35 single family homes, each priced between $400-$500K US. Superintendent 2 was responsible for a subdivision of 51 single family homes, each priced between $350-$450K US. Superintendent 3 was responsible for 125 multi-story townhouse units located in 23 buildings with 6-8 units per building. Prices of the townhomes ranged from $275-$350K US per unit.

Each superintendent was individually interviewed to identify their work methods and the information exchange techniques they used during construction. Each was asked to explain their perception of building a house including construction tasks such as foundations, framing and information flows such as phone calls and inspections. The process was interactive with interviewers asking clarification questions during the interview to more accurately understand workflow and information sequences. These interviews formed the data for the superintendent baseline process maps used in support of field observations. Thus field observations began with a total of four process maps. These being one corporate task sequence map and three superintendents' work processes maps.

3.1 Data Collection

Qualitative methods for data collection are useful for understanding the processes behind observed results and acknowledging changes in people's perceptions. The categories of qualitative methods most commonly used in process evaluations are interviews, questionnaires, observational methods, document review and focus groups (World Bank, 2000). For this work a combination of informal conversational interviews and direct observation techniques were used to capture and record data.

Informal conversational interviews, allowed the researchers to document the superintendent's perceived baseline processes. This interview process was followed by direct observation of each superintendent. Direct observation allowed for the systematic noting of each superintendent actions without reliance on the 89 day corporate schedule or individual's perceptions. Thus these observations could focus on communication interactions as well as task stimulus. One advantage of direct observation is the ability to observe not only what happens, but what doesn't happen, and what isn't heard and/or is filtered out by the participant (Taylor-Powell and Steele, 1996). A drawback as noted by other researchers is that not every event or subject can be observed (World Bank, 2000).

The direct observation method was successful in revealing the superintendent's daily activities, work interfaces and the resources they use during the construction process. This information was used to develop the input/output needs for informational transformation. It also validated the mapping accuracy of the superintendents' perceived processes.

3.2 Process Mapping

Process maps are qualitative static models, meaning they provide little or no quantitative analysis and are intended for documentation and conceptualization (Harrell and Field, 1996). Anjard says it best, "A processes map prompts new thinking about how work is done (Anjard, 1996)." This study uses unstructured process mapping tools to provide a simple and flexible interface for documenting and

evaluating the flow of information and its interaction with task actuation. The intent being to transform and re-engineer established field practices.

4. WORKFLOW ANALYSIS

4.1 Original Baseline Process Maps (OPM)

The original builder process map (OPM) was obtained from previous research (Wakefield et al. 2001). This OPM, portions of which are shown in Figure 3, is a simple representation of the overall construction schedule, depicting only construction tasks and subcontractor inputs. . For this study the OPM was re-categorized to relate previous research to the current investigation. Numbers were assigned to each construction task to relate to identical construction tasks on the superintendent process maps, portions of which are shown in Figure 4. Construction task were categorized and labeled 1 to 21. The categories on each process map refer to the same construction tasks, regardless of superintendent work flow being mapped. No other graphical or sequential modifications were made to the original process map.

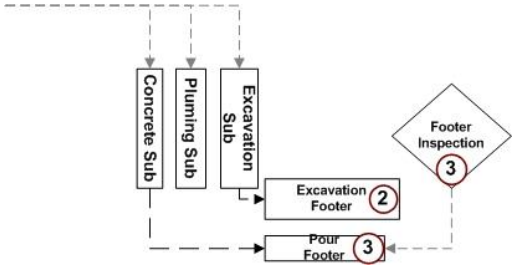

Figure 3 - Portions of the Orginal Baseline Process Map – (OPM), (Wakefield, et. al., 2001)

4.2 Information Categorization

Figure 4 shows an example of the construction task "Excavate Footer" for one superintendent with delineated fields. This is the same corporate construction task noted as a circled 2 in Figure 3 above; although it has been expanded to include actual subcontractor task and superintendent information flows. Thus Figure 4 combines both task and information fields into a single chart, shaded circles represent *"actions"* or construction tasks and rounded rectangles represent **"information flow**.**"**

These fields contain the identifiable information flows and management tasks that make a construction task actuate, in effect "ready," and "set" points, with "go" being the scheduled activation date. Font style and color coding are used to visually identify the information mechanisms including telephone call, e-order, web access, and fax. Vertical arrows link successive activities, or activities that happen on different days. Horizontal line segments link coinciding activities or activities that happen on the same day.

The process maps were supplemented by a narrative to help refine the information flows. The "Excavate Footer" narrative verbally describes Figure 4 and uses **bold** font for **information exchange** mechanisms and *italic* font for *construction tasks*. This provided researchers visual assistance in analyzing the data, particularly the distinction between information and task, or trigger and action.

4.3 Informational Analysis

Analysis of the superintendent's information flow began with a comparison among all the process maps. As stated earlier, the original process map (OPM) contained twenty one basic construction

tasks and no information flows (Wakefield, et. al., 2001). The three superintendent maps contained both construction task and information flows within the same 21 task categories. This enabled verification of the established corporate process with actual field practices and enabled the analysis of what information triggers a construction task. Thus "ready," "set," "go" points were identifiable from three separate sources. In effect a construction task (ready point), activated an information flow (set point), and the web schedule establishes the "go" point.

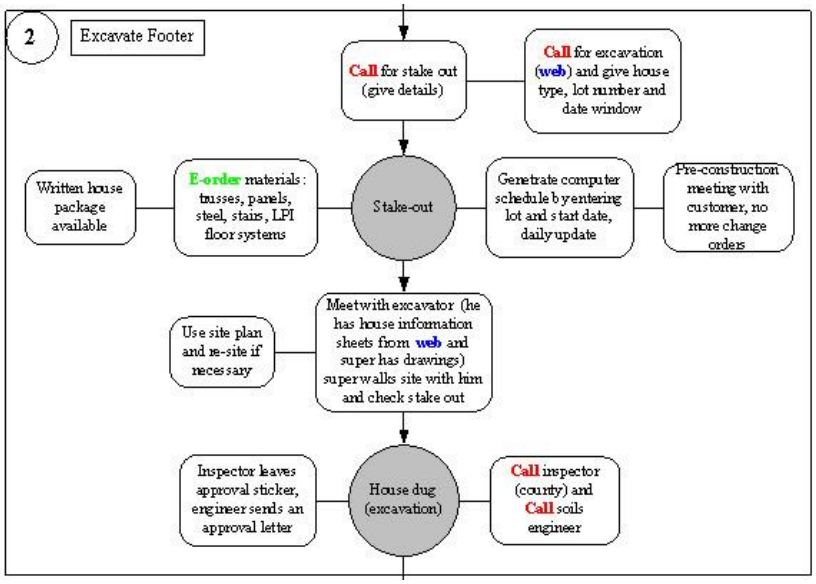

Figure 4 - Partial Activity Information Process Map- Activity 2 – Excavate Footer

The analysis also revealed inefficiencies in work task and information flow. Project schedules changed daily due to varying factors predominantly subcontractor reliability. A major factor interrupting subcontractor performance is organizational competition. Subcontractors are working on multiple subdivisions and thus the builder and/or superintendent may not receive first priority. The competition extends, among different superintendents, within the builder's own organization. This performance failure forces the superintendents to update each house schedule daily. The web based management system has made this simple although remote computer access makes it cumbersome.

Another finding is that many subcontractors self schedule using the web based system but then call to verify the schedule. Reliability in real-time scheduling would make this an unneeded redundancy. Other problematic issues identified are subcontractors not checking the web schedule with adequate frequency, subcontractors not using the system, and subcontractors in apparent mistrust continuing to call the superintendent to verify online schedule accuracy.

4.4 Daily Activity Analysis

The daily activities reveal that the three superintendents, each at a different location have similar daily routines. First, they walk the site carrying paper schedules and house information sheets with them. These are obtained from a single computer in the sales office. Therefore to complete this activity the superintendents must first go to the sales office, log on to the web based management system, print out hard copies, and then travel to the individual houses. At the site, paper lists are generated then later rewritten into sorted lists. As schedule updates are needed they are currently marked up on the paper schedule and then update when the superintendent returns to the sales office and accesses a computer terminal.

4.5 Observational Analysis

Observed site information data was sorted into a generic "information type;" phone call, list, log, drawing access, web, and others. After review it was obvious that the data needed further simplification to adequately compare each "information type" across all three superintendents. In order to draw consistent conclusions as to similarities and differences, the informational exchange was further organized within shaped boxes, a different shape for each superintendent. This enabled the data to be graphically represented, making data extraction and sorting much easier. This graphical analysis resulted in commonality of "information type" among superintendents. This being drawings, lists/logs, web based management, paper documents and telephone calls. This was subsequently recast as identifiable information management domains of scope, schedule, procurement, payment, and monitoring/reporting.

Table 1- Information Domain and Type

Information Domain	Scope	Schedule	Procurement	Payment	Monitor/Report
Information Type	Drawings/Information Sheet	Web Schedule	Web E-order	Web Pay Authorization	Calls/Lists/Logs

5. PROCESS TRANSFORMATION

Process maps and on-site observations knowledge were used to make conclusions about the adequacy of process transformation for superintendents. The three main geographical work areas identified for each superintendent were the job trailer, sales office and site (the lot of the home under construction). The superintendent is required to travel between the sales office, job trailer, and the site for such things as computer usage, consult or pick up drawings, fax machine use, and to gather, enter or consult log books. This process is inefficient and in some cases delays subcontractor work. If data could be transformed into information when and where needed, the superintendent could then address other issues. Within the superintendent's information management domain, then and there information transformations that mimic the superintendent's working techniques were identified. These information subsets identified earlier use the superintendent's vernacular, and are noted further in Table 2.

Table 2 - Field Information Mechanisms

Drawings	Used with varying frequency. Primarily at start, at inspection and when questions arise. Minimal drawings required are site plan and floor plans.
Lists	Multiple paper lists generated daily, all subsequently rewritten to categorize by subcontractor. Considered a dominant field management information mechanism.
Web Management	Administered remotely at the sales office or job trailer. Usual output is a complete schedule or a 2 week schedule or both per superintendent preference. Schedules are hand marked in the field and electronically updated in the office. E-orders and payment authorizations are made from data compiled in daily lists.
Paper Documents	Paper based logs, including an appliance log, field order log, and weekly walk through lists are utilized.
Phone Calls	Mobile telephone calls were the most frequent daily communication mode and made through a direct connect system. Absent is full contact information during communications.

Thus the research indicates that alternative techniques to automate data collection and its transformation into formats consistent with a superintendent's working techniques have great benefit to residential supervision. Alternative electronic processes were envisioned and categorized within the previous identifiable information domains. A transformational approach using menu driven access charted onto the superintendent's organizational techniques, communication mechanisms, and daily activities was initiated and configured as shown in Figure 5.

5.1 Transformation Recognition

Figure 5 was created as a hierarchical menu structure with the intent to incorporate informational domains that can contribute to work process transformation, be easily navigated and become user friendly. The transformation once implemented is intended to alter current field practices, including reduced trips between job trailer, sales office and site, reduced need for paper documents, and making daily communications quicker, easier and site focused.

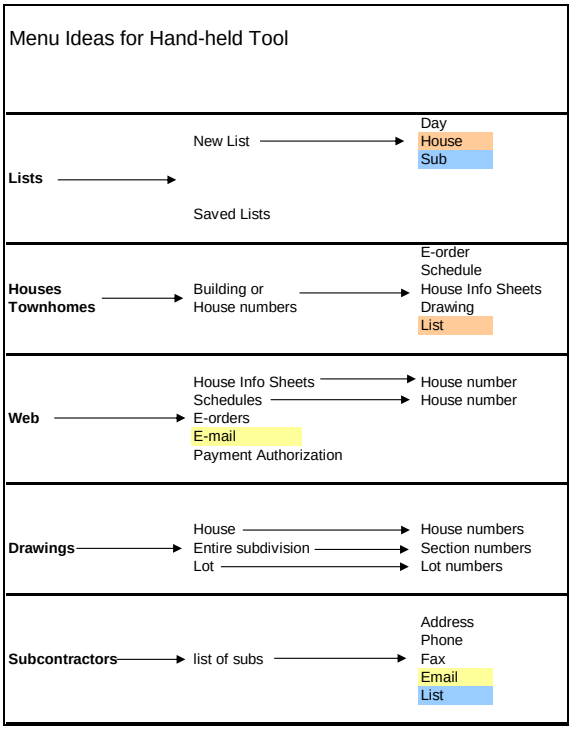

Figure 5 - Formalized Information Structure

6. CONCLUSIONS

The analysis of the data collected reveals that each superintendent supervises their projects using similar information mechanisms. These mechanisms were determined to be drawings, lists, web based management, paper documents and phone calls. These information mechanisms fall within identifiable management domains of scope, schedule, procurement, payment, and monitor/reporting. The different informational resources needed each day to build a house were identified and linked. Alternative opportunities for process improvement through real-time information access were identified and categorized for transformation and implementation into a hand-held electronic tool.

The daily activities analysis reveals opportunities for parallel transformation of an individual superintendent's work processes. Each superintendent creates, organizes, and rewrites paper lists at the end of the day. The purpose of these lists being to organize and sort data for input and transmission to subcontractors to trigger an action. An electronic tool could eliminate double entry through drag and drop, sort, transfer, and upload options. The trigger list could easily be sorted into separate subcontractor and house lists in a matter of seconds.

Additionally the hand-held e-tool would be beneficial for on-site access to any of the web based project management functions. Although the web based management system has made significant improvements to real-time information access there are still barriers to overcome in redefining the field practices of supervision. At present the schedule is monitored on-site via paper documents, as is

the need for material procurement. House information sheets which define the project scope and specifications are only accessible via remote computer and are the initiating source for project changes. As Christofferson's work points out poor scope communications are a major cause of financial loss on any residential project (Christofferson, 1999). Thus real-time access to scope changes, and updated schedule information at the site should improve communications and minimize unnecessary and non-intended actions by subcontractors and increase subcontractor trust in the validity of an on-line schedule.

Further revealed as a result of the process analysis was a common work flow among the superintendents with relatively minor differences. The cross-function task of supervision and management in residential construction indicate the need for better on-site management tools particularly capitalizing on the already in place web based management system. Since a common work flow was identified it is believed that a common transformation can be made across the organization. Work is continuing as a result of this study on developing and integrating a hand-held electronic field tool as an expanded field supervision/management component of the web based management system.

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