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POINTS ON CONSTRUCTION

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ABSTRACT

"Points On Construction (POC)" is a site network tracking system based on a platform system of collaborative intelligent construction management that has two holds. One is a back office management system in maintenance and service applications for construction machinery. Another is a comprehensive, web-enabled management system to support day-to-day construction management. The POC is able to capture and collect field data pertaining to works at points on construction activities, and automatically sends the field data to the platform system, which in turn could automatically generate daily and monthly reports. User can easily access to these reports. First, this paper presents related research and developments. Secondly, described are framework of the POC and lessons learned from the experience in deploying the POC to a road construction. Finally this paper presents remarks and further research.

KEYWORDS

Points on construction, Collaborative intelligent construction management, Machine management system, Construction management system

1. PURPOSE AND SCOPE

In the Japanese construction industry, there are some problems as follows:

- In general, a construction project is partitioned into several construction projects that are executed by different organizations, For example, the road construction is partitioned into several

projects by each approximately 500 m in length, which are managed by different contractors, and
- A construction process is separated into several works that are independently performed by different subcontractors. For example, road construction includes a series of discrete works such as excavation, loading, transportation, unloading, grading, compaction, etc., which are performed by different subcontractors.

On the one hand, various machines and diverse computer systems come from different manufacturers. There are few standardized interface between them.

Consequently, it becomes difficult to gather field data regarding work operations and to grasp work in progress.

To overcoming the above problems, we have been and are trying to build a platform system of collaborative intelligent construction management that aims to improve constructability [1]. In other words, it means timesaving in wait, and reduction in re-works and repair-works. In this study, construction is regarded as a process rather than a series of discrete works. Although discret works are independently executed by different subcontractors, each progress rate is interdependent in a construction process. The platform system could integrate information processing throughout the whole construction process of discrete works such as excavation, loading, transportation, unloading, grading, compaction, and so on.

This platform system comprises a machine management system and construction management system. The machine management system is a multi-language internet-based back office management system in maintenance and service applications for construction machinery. The construction management system is a comprehensive, web-enabled management system to support day-to-day construction management.

"Points On Construction (POC)" means a site network tracking system, which is linked to the platform system. It captures and collects field data pertaining to works at points on construction activities, and automatically sends the field data to the platform system, which in turn automatically generates daily and monthly reports. Resident engineers, supervisors, and others could easily access to these reports by the Internet.

First, this paper presents research and developments of the plaform system linked to the POC. Secondly, described is a framework of the POC for a road construction and a land development. Thirdly, shown is lessons learned from the experience in deploying the POC to a road construction. Finally, this paper reports remarks and further research.

2. RELATED RESEARCH AND DEVELOPMENTS

2.1. Machine Management System

The machine management system, which is called "Global e-Service," is a multi-language internet-based back office management system in maintenance and service applications for construction machinery. It is able to monitor and control machine production with a satellite communication system, GPS positioning system, and on-board computer, and is served worldwide as shown in Figure 2.1.1.

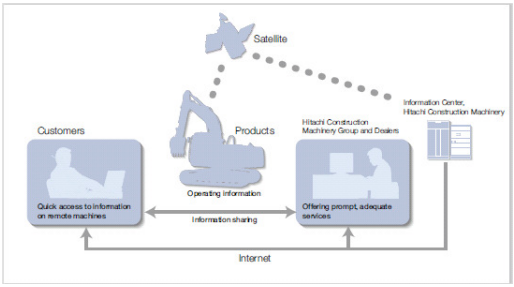


Figure 2.1.1 bird-eye view of global e-service

Each machine regularly sends its operational data via a satellite communication system to a server for the Global e-Service. In turn, data preserved in the server is automatically processed to generate administrative information on machine operating conditions, which each user around the world is able to access by the Internet. Examples of the administrative information include:
- Operating conditions, operating hours per day and fuel level;

– Positional information gained by GPS that displays machine position on map;
– Scheduled machine maintenance such as periodic maintenance schedule or record;
– Machine operation and maintenance record; and
– Machine servicing log.

Figure 2.1.2 shows example of relevant machine operation information such as daily-pictorial engine status, hourly functions, utilization monthly, and alarms and faults.

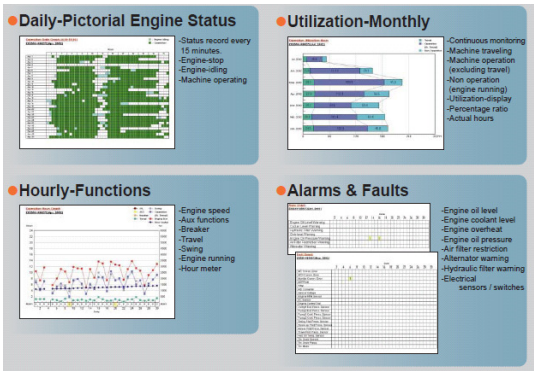
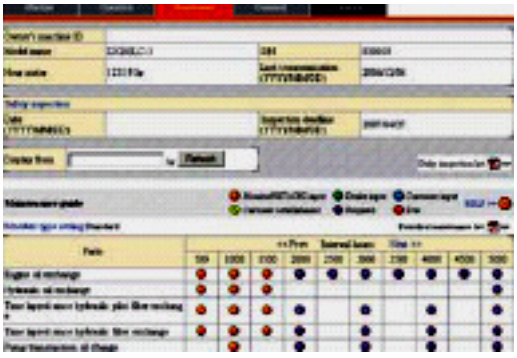


Figure 2.1.2 machine operation information

Figure 2.1.3 shows example of maintenance information, which includes maintenance history as well as recommended maintenance due for each machine.



Fgiure 2.1.3 maintenace information

Figure 2.1.4 shows example of geographical position of each machine with serial number identification.

The Global e-Service will present an up-to-date overview of all operational information and location of each machine. It will also allow for specific multiple machine searches using specific operational information as search criteria. It enables users to flexibly take steps against the occurrence of unexpected machine troubles and to reduce repair costs. If the machine fails, the operator can make diagnosis from alert information, finding causes of a failure.

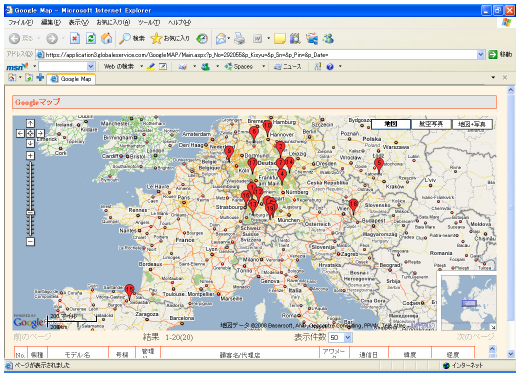


Figure 2.1.4 example of geographical position of each machine

Thus, the Global e-Service will promptly provide optimum servicing to each user, and encompass the management of all aspects relating to a company's machine fleet from the allocation resources to fuel economies.

2.2. Construction management system

The construction management system, which is called "collaborative construction management professional (c2mProfessional)", is a comprehensive, web-enabled menagement system to support day-to-day construction management. The c2mProfessional has a variety of functions to manage information on day-to-day construction activities. Relevant functions of those might be chosen and assembled as being proactive to customer's needs and job-site conditions, and would be provided as ASP service for construction authorities, contractors, subcontractors, and others.

The c2mProfessional consists of construction target management system, work management system and

construction profile management system. The c2mProfessional makes process control loops with electronic data exchange among them as shown in Figure 2.2.1.

The c2mProfessional has selection and display menu, that is, levels of security right down to the individual field level. It is able to ensure that only properly authorized individuals have access to certain confidential data or the ability to delete important information.

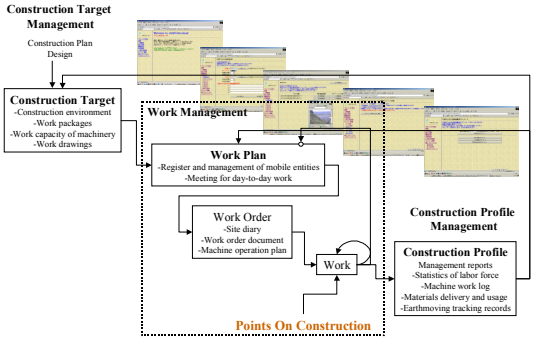


Figure 2.2.1 framework of c2mprofessional

The construction target management system is utilized for clarifying and allocating operations to reserve enough capacity of equipment for achieving a given goal. The construction target management has functions to calculate the expected capability of equipment being used in a construction project. Examples of the caluculation include:

- Productivity per hour of machines such as backhoe, dozer, scraper, etc., and
- How many dump trucks are required to match the productivity.

These functions allow resident engineers and supervisors to choose the best construction resources for the task routing and scheduling. By utilizing the construction target management system, examined are the following matters, but not limited to:

- Sizing fleet of machines right,
- Minimizing transport movement,
- Optimizing material usage, and
- Planning allocation and performance of construction machinery, dump trucks and on-site personnel.

The work management system has a database to manage basic data and field data regarding construction activities. The basic data represents fleet properties. The fleet means the complement of construction machines, trucks, workers and communication tools that are operating together for day-to-day works charged on job site. The field data means as-built data that are captured and collected with date and time stamp at points on day-to-day construction activities by the POC as described later.

The construction profile management system presents information on construction profile. The construction profile is defined as a set of data to vision characteristics of phenomena being generated along with construction in progress and indices to show their patterns [2]. The construction profile management system could automatically edit gathered field data to produce daily and monthly reports on the construction profile that covers the following matters:

- Work instruction and procurement order,
- Time reporting for employees,
- Statistics of labour force,
- Machine work log,
- Dump truck tracking and dispatch
- Exception reporting regarding dump truck,
- Extra truckloads
- Materials delivery and usage,
- Earthmoving tracking records.
- Force account worked,
- Unsafe conditions and behaviour, and
- Analysis results of work line balance based on shovel and truck productivity.

As mentioned earlier, construction is regarded as a process rather than a series of discrete works. Operations of these discrete works in a construction process interdependently proceed in repetitive fashion and have respectively different pitch times. The pitch time is defined as time need for working one unit out. In other words, it means time between the completion of one unit and the completion of the next. The predecessor's pitch time might impact the successor's one, and vice versa.

Analyzing work line balance shows bottleneck operation. The bottleneck operation means one with the largest pitch time. It is very important to balance workloads, that is, pitch times at points on a construction activities.

Users have a variety of options for editing daily and monthly reports of those including:

– Which reports to print,
– In what sequence,
– Detailed or summary, and
– For what time period.

The each report can be easily reused and revised from user's viewpoints as trends, graph, tables and pre-calculated data for free-use in spreadsheets. It would be able to turn data into more useful information.

3. FRAMEWORK OF POC

3.1. Overview of POC

The Points on construction (POC) is a site network tracking system for mobile entities such as machines, dump truck, workers, materials, and so on. It aims to manage a fleet to ensure reliable construction operations at points on and between borrow area and land fill area.

Figure 3.1.1 shows relationship among the POC, the Global e-Service and the c2mProfessional.

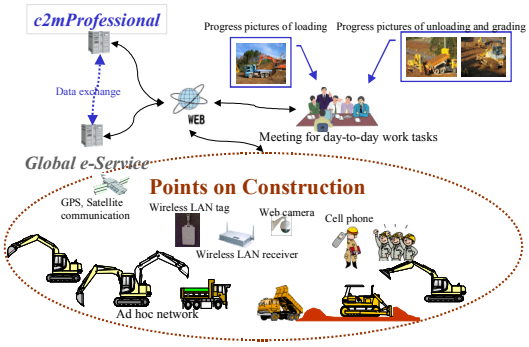


Figure 3.1.1 relationship among POC, Global e-Service and c2mProfessional

As-built data pertaining to works performed at points on construction activities is automatically gathered on near real time basis and entered into the databases of the Global e-Service and the c2mProfessional by utilizing the following technologies:

– GPS Positioning system
– Satellite communication system,
– Wireless LAN, handheld devices, wireless LAN tag, mobile phones, ground station computers on site, and
– Data exchange function based on web service.

The above data exchange function plays a critical role in two holds. One is to automatically and periodically send field data with date and time stamp, which are temporarily preserved in a ground station computer, to a server for the c2mProfessional. Another is to periodically export machine work log from a server for the Global e-Service to a server for the c2mProfessional. Field data of those are finally stored in the database of the work management system, and utilized for future validation.

3.2. Components of POC

Figure 3.2.1 illustrates what technical systems are available and used in the POC. Each technical system is described below.

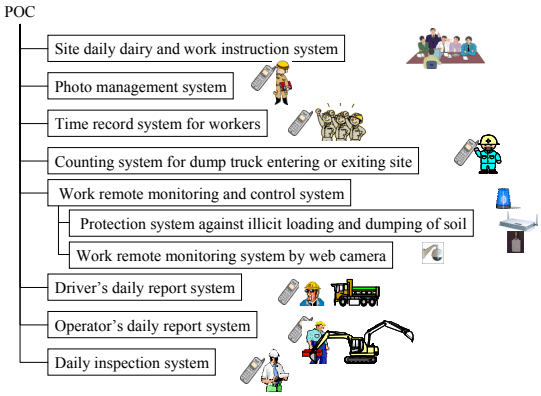


Figure 3.2.1 subsystems of POC

Site daily dairy system keeps a record of daily work plan and instructions that are discussed and decided at daily meeting. Items recorded in the site daily diary system includes:

– Identification of the project,
– Weather conditions such as rainfall, temperature range, visibility,

- Type of work planned and performed,
- Subcontractor's name,
- Gang leader's name,
- Number of workers,
- Number of construction machines,
- Number of dump trucks,
- Location of work place,
- Allocation positions of construction resources on job-site,
- Delivery time schedule of materials,
- Safety and health instructions, and
- Visitors to site.

Work instruction system keeps a record of instructions issued, and allows supervisor to inform gang leaders and others of work plans, schedules, orders, and safety and health instructions, which are discussed and decided at a daily meeting, and recorded in the site diary system.

Photo management system makes it easy to manage photograph in progress regarding construction practices, which are taken by handheld digital camera or mobile phone

Time record system for workers is a master roll system that keeps a record of working hours and days for workers. Workers are able to enter their starting time and quitting time with GPS positioning data in the master roll by their own mobile phone.

Counting system for dump trucks is able to record car number of dump truck that enters or exits job site. Ticket man confirms car number of dump truck and then submits it to the counting system by mobile phone. Time when the counting system received the entry is recorded as the time when the dump truck entered or exited site.

Work remote monitoring and control system consists of two kinds of computer systems. One is a prevention system against illicit loading and dumping of soil by utilizing wireless LAN sensor and tags, and an infrared sensor. Another is a work remote monitoring system by web camera.

The prevention system is a watch-keeping system at gate of job site. Dump truck drivers are obliged to hold their own wireless LAN tags. When a dump truck goes through the gate, an infrared sensor captures its behaviour. At the same time, the MAC address of the wireless LAN tag is automatically captured by wireless LAN sensor, and collected in a ground station computer. If and when the driver should not have her/his own wireless LAN tag, her/his dump truck could be judged as illegal one. Then alarm could immediately sound, and at the same time alarm notice should be sent to the concerned people.

The work remote monitoring system by web camera enables resident engineer and supervisor at their site office to watch work in progress on real-time basis, and automatically preserves the snapshot pictures at designated intervals.

Driver's daily report system is a telltale system based on mobile phone. It enables driver to submit her/his daily work report to the c2mProfessional. This report informs her/his supervisor of driver's name, car number, date, heading, vehicle routing, tonnage hauled, fuel usage, odometer value, and so on.

Operator's daily report system is also a telltale system based on mobile phone by which operator can submit her/his daily work report to the c2mProfessional. This report includes information on operator's name, machine id, work type, work position, work hour, breakdown and standby times, work volume performed, and so on.

Daily inspection system is a field checklist system based on mobile phone. Inspector entries inspection results in punch list displayed on her/his mobile phone and submit them to the c2mProfessional. If he/she should find something wrong on the job site, she/he could immediately inform the concerned people of the wrong phenomena. In addition, resident engineers, supervisors, and gang leaders are able to see the inspection results at any time and anywhere by accessing the c2mProfessional.

4. LESSONS LEARNED FROM CASE OF ROAD CONSTRUCTION

4.1 Equipment Installed

The POC was deployed to earthmoving operation in a road construction project. In this road construction project, approximately 30,000 m3 of borrow soil

should be hauled to the other road construction project, which was approximately 5 km away and was executed by different contractor.

Figure 4.1.1 shows configuration of equipment being installed in this project.

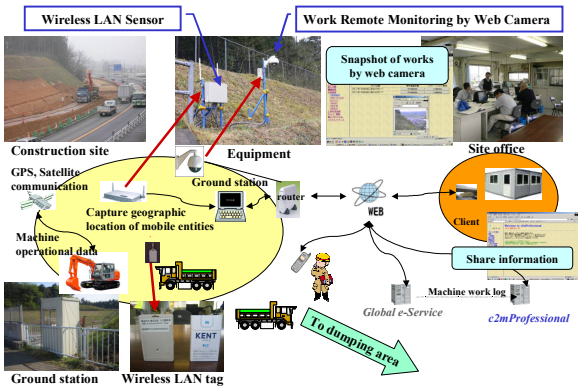


Figure 4.1.1 configuration of poc in this project

4.2 Web Camera

In order to remotely monitor works, web camera was installed in a fixed position at the job site. Watching picture progress of loading states, supervisor could easily understand the actual work in progress on real time basis, and in turn take proactive steps toward improvement, immediately when facing abrupt change in work conditions.

By supervisor's opinion about the web camera, it is convenient to understand work in progress related to the following matters:

- Change in weather, for examples, sudden rainfall, thunderstorm,
- New work while being erratic,
- Water run-off on site,
- Site conditions when typhoon or earthquake comes,
- Worker compliance, and
- Quality that depends on time passes.

4.3. Wireless LAN Sensor and Tags

In order to to manage earthmoving operation, wireless LAN sensor was installed beside the web camera. Dump truck drivers were obliged to always hold their own tags. The wireless LAN sensor could automatically capture the MAC address with data and time stamp when dump trucks entered or exited the job site. Data of the MAC addresses were temporarily stored in a ground station computer, and then periodically and automatically sent via the Internet from a ground station computer to a server for the c2mProfessional.

Backhoe being used in this project regularly sent its operational data via a satellite communication system to a server for the Global e-Service. It presents machine work log such as backhoe position, daily operating hours, fuel level, and so on. These data were automatically and periodically exported from the Global e-Service server to the c2mProfessional server.

In turn, the construction profile management system automatically generated daily and monthly reports, which included the following matters:

- Identification of dump truck,
- Load frequency to dump truck,
- Time when entering or exiting site,
- How long each dump truck stays on the job site,
- Round trip time of dump truck between the job sites,
- Number of cycles, and
- Backhoe's operational data such as work positions, work hours, fuel usage.

4.4 Advantages

It is important that number of trucks could match capability of backhoe in order to haul soil as efficiently as possible. Dividing the average round trip time of dump trucks by the average length of their stays on the job site, it could be seen how many dump trucks were needed. It suggests which might be better, to increase in number of backhoes, to conversely decrease in number of dump trucks, or otherwise.

Analyzing data regarding the round trip times might show which drivers have undesirable behavior such as long lunchtime or long round trip time tendency, which might negatively impact productivity of earthmoving operation. If undesirable behaviour of the kind should be found, it became necessary to

remind them of awareness of the right speed and the appropriate volume in a regulated manner.

In this project, it was not necessary to assign ticket man, and issue item quantity ticket or load tally sheet, because daily report of earthmoving operation could be automatically generated based on actual and time-stamped data. More over, operators and drivers were always able to know their own muster roll and work account performed by using their own mobile phone to access the c2mProfessional.

4.5 Shortcomings

Wireless LAN sensor was not installed at the opposite site where the borrow soil should be transported to. This is why it was controlled under different contractor. Because of that, how long it takes dump truck to stay at the landfill area was unknown. Actually, according to unexpected changes in work condition at the landfill area, dump trucks have unexpectedly and often been put in wait to unload. Consequently, the earthmoving operation often became erratic.

If both sites should effectively communicate with each other, waiting time and rework could be reduced, and dump truck usage would be more optimized.

5. REMARKS AND FUTURE WORKS

Taking in account construction as a process rather than a series of discrete works, the POC enables site personnel to collect, coordinate and handle information on construction process and proactively make appropriate adjustments based on factual and time-stamped data. Taken together, the POC gives us advantages that site personnel could gain opportunities to:

- Connect the site office and the headquarter to the job site;
- Easily gain work reports pertaining to work operations;
- Monitor and track mobile entities, and check the current status of all work operations;
- Improve the understandings of on-site operations;
- Understand on-site inefficiencies such as bottlenecks among construction resources; and
- Take steps against the bottlenecks and improve the cycle times.

The above advantages enables site personnel to evaluate force account performed at cross section and toward longitudinal in construction progress from the following viewpoints:

- Viewpoint 1: Watch line balance, for example, search unbalance of productive capacity among construction resources;
- Viewpoint 2: Search outliers, for example, find construction resources that have extra-high production capacity and them in the opposite side;
- Viewpoint 3: Watch state of control, for example, look at tendency toward expansion or reduction of variance compared to the average value;
- Viewpoint 4: Watch productivities, for example, look at planned and actual productivities of a work package, and make a comparison between the two; and
- Viewpoint 5: Look at construction speed, for example, first, set base line of construction progress; secondly, calculate actual progress rate, and finally make a comparison between the two.

In the next future, we will apply the POC as a prevention system to a land development project. In this project, there is a long-haul distance more than 30 km between the borrow area and the land fill area. Problems here are:

- Illegal (unauthorised) dump truck might steal good soil from the borrow area,
- Dump truck might illegally unload borrow soil at undesignated area, and
- Illegal dump truck might throw away topsoil, and, organic matter, demolition debris, and other unapproved material at the land fill area.

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