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Development of web-based support system for on-line optimization

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Abstract−On-line optimization is a very powerful tool that saves costs and improves the operational productivity of a chemical plant. However, the process of on-line optimization takes too much time and cost because it needs the significant contribution of process optimization specialists. To solve this problem, a web-based support system for on-line optimization is designed. The design specifications of the target product are identified using product design tools such as house of quality and roof correlation matrix. The design specifications are implemented into three product modules: communication module, project management module, and information interaction module. The final prototype system is evaluated based on a real application to the on-line optimization of a PTA process. The system shows both the time and the cost could be reduced by 43.5% and 43.3%.

Key words: Optimization, Web-based System, Product Design, PTA Process, House of Quality

INTRODUCTION

On-line optimization is a very powerful tool that saves costs and improves the operational productivity of a chemical plant. Introducing on-line process optimization, chemical industries are able to operate chemical processes more effectively and produce high quality products in spite of increasing costs of raw materials and energy [1,2]. To perform on-line optimization more effectively, many leading companies introduce new technologies such as process information systems, programmable logic control, and distributed control systems. Thus, on-line optimization has become useful technology in deciding the optimal operation conditions, and approximately 250 commercial online optimization systems have been installed in the process industries. Most of these projects have been initial and/or commercial successes [3].

Although process optimization is effective technology, many companies which want to adapt this have to pay many expenditures and much time to improve their unit performance. The reason is that many chemical facilities were built in the remote coastal and rural areas, whereas most of the experts who can solve the chemical process problems live in the large cities. Thus, experts and companies have to consume much time to gather opened and/or hidden information such as process operating constraints and to review data analysis results to make the optimization model. Also, experts have to be invited to the spot to analyze causes of the process operating problem. This is because most of the useful knowledge is possessed by operators or process engineers as long as process optimization is under way. Due to expensive consulting fees and ineffective project progress, many companies have hesitated to introduce optimization projects in spite of their effectiveness. Thus, expert consulting at cheaper price is needed in the process optimization project.

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There's some system for on-line service for long distance as a benchmark. Internet application technologies which give many opportunities for exchanging information are rapidly being developed. The cost-effective growth of its technologies give opportunities for applying large-scale distributed applications. In this field, the most effectively applied case is tele-medicine. Tele-medicine is the application of telecommunications technology to the communication and control tasks of health care, which employs the benefits of telecommunications to transcend barriers of time and space [4,5]. For a long time ago, medical tele-consultation was serviced by use of telephone and transmitting written opinions to soldiers and remote area's inhabitants. Recently, high performing web-based medical services are provided because the technologies related to medical services are being developed, such as ultrahigh speed internet networks, multimedia software, and various types of medical diagnosis tools. Other web-based application fields are tele-diagnosis in aquaculture, risk assessment of gypsy moth [6,7]. One of the highlights of these systems enables remotely placed customers to be provided some of the cost-effective expert consulting services. A management system for an optimization project can be presented as a clue.

The aim of the present paper is to suggest a solution which overcomes the limitations of previous process optimization as well as ensures high quality of optimization consulting for the companies located in rural and remote areas. The product design methodology is applied to propose a solution by developing a web-based support system for on-line optimization [8,9]. A web-based on-line system for compressor network optimization is suggested as a case study.

DEVELOPMENT OF THE TARGET SYSTEM

The target product was the solution of time and cost problem of the process optimization project. So, task analysis of the optimization project was needed. By this analysis, the main step of time and cost consumption was identified. The specification of the final prod-

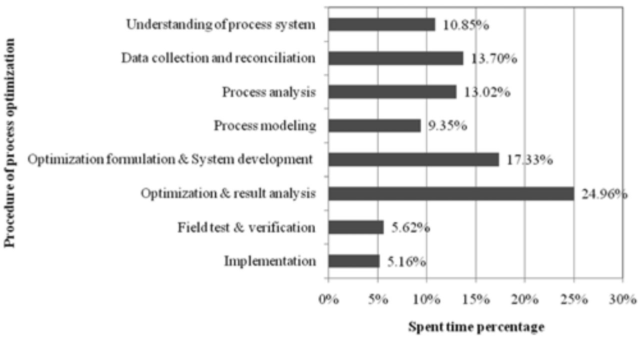

Fig. 1. The procedure of the on-line optimization project.

uct was able to be established by this analysis. The procedure of the on-line optimization project is divided into eight steps in Fig. 1. From understanding of process systems to implementation and maintenance, there are five main steps of time and cost consumption.

However, this chart does not show the possibility of how much time is reduced. For example, the optimization formulation step is the most time consuming. But in this step, there's little time to reduce in this step because most time activities of this step are performed in front of a desk. So, the need for analysis of the activities in each step was needed.

To find the relationship of the steps and the activities, the House of Quality (HOQ) was used [10,11]. By this method, the causes of time and cost consumption were identified. For identifying the degree of the relationship, several experts who had performed the optimization project were interviewed. The experts responded to a questionnaire including the weight of each step and the relationship. Fig. 2 shows the resulting HOQ. The causes of time and cost consumption are identified. By HOQ, the time importance of the activities could be found. Fig. 3 shows the rank of time consuming. The activity of discussion is the most time consuming activity, and midterm assessment follows. Explanation of technique and knowledge, adjustment of discussion schedule, and verification of literature are insignificant because these activities were weak time consuming result. So, there were eight main activities for time consuming.

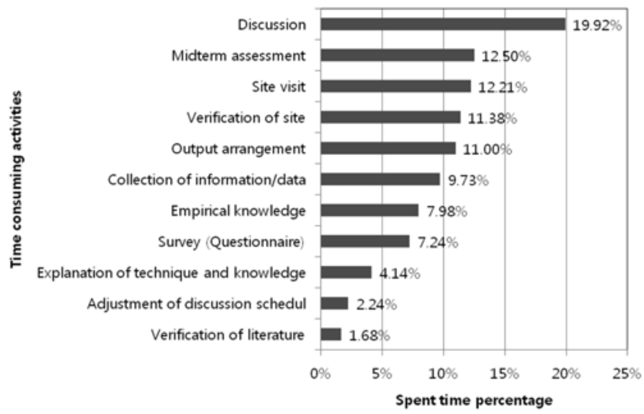

Fig. 3. The rank of time consuming activities.

However, the solution for time and cost reducing was not clear. These activities are not independent. For example, the activity of discussion needed the activity of site visit for smooth communication. So, we could categorize these activities. It means that the analyses of relationships between activities were needed. For identifying the relationship between activities, the roof correlation matrix was used [12]. Fig. 4 shows the result of the roof correlation matrix. These activities were able to be categorized by this matrix. For example, the activities of discussion, site visit, and collection of empirical knowledge were related with a strong relationship. They were performed on the plant site, so they were grouped with visit of site. Also, the activities of midterm assessment and output arrangement were categorized as assessment.

By analysis of the roof correlation matrix, we could categorize the eight activities into three independent groups. Discussion, site visit, and collection of empirical knowledge were categorized in activities with visiting site group. Output arrangement and midterm assessment were categorized in assessment group. Finally, verification

Relationship: ⊙ Strong relationship = 9; ○ Medium relationship = 3; ▽ Weak relationship = 1

Optimization procedure	Time / Cost consumption	Site verification	Questionnaire	Explanation of technique & knowledge	Site visit	Collection of empirical knowledge	Output arrangement	Discussion	Collection of information and data	Verification of literature	Adjustment of discussion schedule	Midterm assessment	Weighting factor	Relative time consumption	Absolute time consumption
Step1. Understanding of compressor system	Collection of process, equipment, and sensor's information	○	⊙		⊙	⊙	○		⊙		○	▽	0.13	5.59	0.058
	Collection of compressor system events data	○			○	⊙	▽		⊙		▽			3.25	0.034
	Understanding of compressor system	▽			▽			▽				⊙		1.56	0.016
⋮															
Step6. Analysis and training	Collection of data after optimization	○	○		▽		▽		○		▽		0.11	1.43	0.015
	Analysis of efficiency and discussion			▽		○	⊙	⊙	○		▽	⊙		3.96	0.041
	Training of compressor operation			⊙	⊙		⊙	⊙			▽	⊙		4.95	0.052
Importance weight	Absolute	10.15	6.46	3.69	10.89	7.12	9.81	17.77	8.68	1.50	2.00	11.15			
	Relative	0.114	0.072	0.041	0.122	0.050	0.010	0.199	0.097	0.017	0.022	0.125			
Technical rank		4	8	9	3	7	5	1	6	11	10	2			

Fig. 2. House of quality for cost and time of process optimization.

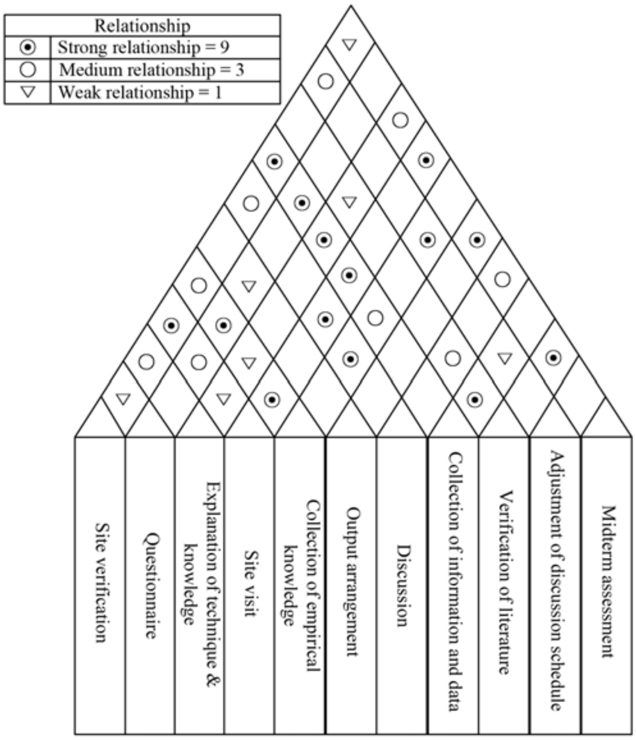

Fig. 4. The result of roof correlation matrix.

of site, survey, and collection of information and data were grouped in collection of scattered information group. To sum up, we could identify three activity groups of root causes for time and cost consuming.

The time and cost were able to be reduced by solving problems in each group. It means that the product specifications were identified by finding solutions for each group. The specifications were determined in modules. First, activity with visit of site was related to communicate in site. So, a communication module was suggested. Second, assessment was related to management of the optimization project. So, a project management module was suggested. Finally, collection of scattered information was related to interaction between people. So, an information interaction module was suggested. These were the final specification of the target product in Table 1.

The specification as the suggested modules needs detailed sub-functions. Search for candidates of the sub-functions is operated. As a result, six candidates were generated in the communication module. These candidates are sorted to three conceptual modules: the synchronous module, the asynchronous module, and the computer-supported cooperative work module. The synchronous module helps users to communicate concurrently. The audio/video conference module and the chat module are suggested as the synchronous communication module. The asynchronous module helps the users to work without regard to time. The web-alarm module and

Table 1. Categorization of activities into independent group and design specification identification

Activity	Independent group	Design specification
Discussion Site visit Collection of empirical knowledge	Activity with visit of site	Communication module
Midterm assessment Output arrangement	Assessment	Project management module
Verification of site Survey (Questionnaire) Collection of information/data	Collection of scattered information	Information interaction module

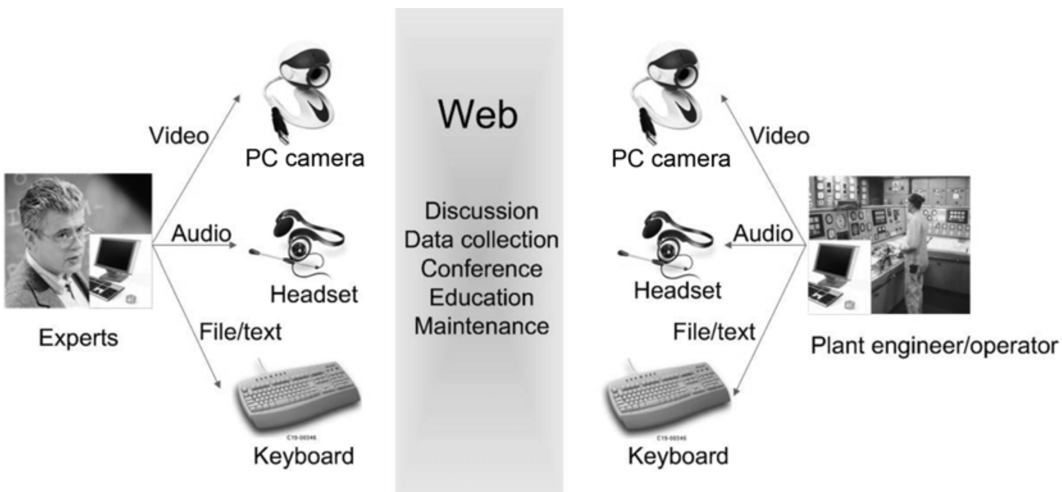

Fig. 5. Design specification: Communication module.

the confirming previous audio/video conference module are suggested as this module. The computer-supported cooperative work module can make users to cooperate more effectively [13]. It can make the users to hold the information in common. The shared documents/files editing and the electronic white board are suggested. These modules are ineffective as individual work; however, when they are combined, the synergy occurs. For example, the audio/video module is not effective for explaining complex information such as process modeling. But with the shared documents/files editing and the electronic white board, this combined module is able to help users explain the complex information. With the asynchronous module, time limitation which the other modules cannot settle is reduced. By confirming the previous audio/video conference module, discussion-absent users can confirm the discussion result. Therefore, the suggested six modules are used as sub modules of the communication module. Using these sub-modules for communication modules, the communication equipment is needed (shown in Fig. 5). The PC camera and the headset are needed for the audio/video conference module and the keyboard is used for the chat module, the shared documents/files editing and the electronic white board.

In the case of the project management module, the management of the process module and the management of decision and change module are suggested as sub-modules. The developed project management module is shown in Fig. 6. For management of process and output, the management of process module is suggested. There are many project management module candidates. In these candidates, a Gantt chart is chosen. The Gantt chart is effective for managing the schedule of the total process and to represent information of schedule and sub-process output [14]. Therefore, the Gantt chart is used as the management of process module (see upper part of Fig. 6). The management of decision and change module is suggested for discussion-absent users. This sub-module is shown in the lower part of Fig. 6. To impart information of decision and change in project, this module represents information of project with a Gantt chart.

Also, the information interaction module consists of two sub-modules: the information/knowledge request module and the questionnaire module. Total information and knowledge requests are represented in the web by the information/knowledge request module. An example of the developed web module is in the upper part of Fig. 7. With this web module, the collection of information is more convenient. Through feedback function in this module, project delay is also reduced. The questionnaire module located in the lower part of Fig. 7 is able to help the experts to collect opinions of many operators and engineers. Through this module, opinions are collected more quickly and cost of off-line questionnaire is reduced.

To test the selected module, a prototype was made. Then, expert groups and operator/engineers assess the prototype. There are some refinement targets which are mainly raised as a problem. Analysis of problems gives the solution to improve. For example, some operators feel uncomfortable in using the communication module due to insufficient experience of use. Thus, a solution is suggested that comfortable GUI is applied to the module. For aack of understanding in the project management module, coupling with the communication module is needed. This solution is applied to solve the prob-

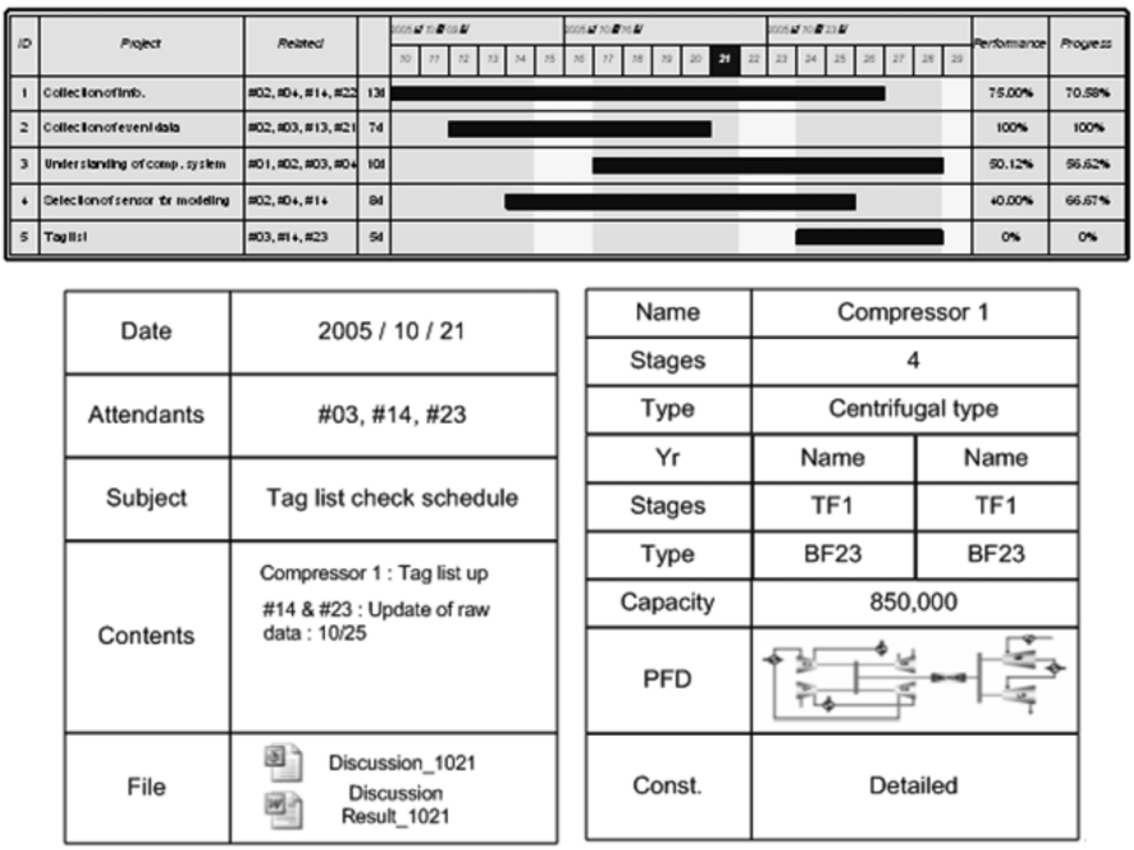

Fig. 6. Design specification: Project management module.

No.	Request	Counter part	Request info.	Progress	Due date
1	#03	#11, #12, #21	Deduction of improvement point through off-line simul.	Continue	2005/11/10
2	#03	#12, #22, #23	Operation bound of comp-1 and expan-2	Continue	2005/11/03
...	...	...	...	...	...
11	#02	#03, #11, #12	Modeling analysis data for comp-1, comp-2	Finished	2005/10/25
12	#04	#11, #12, Team 20	Survey for grasping compressor characteristics	Finished	2005/10/21

Revise Delete Finish

Request info.	Modeling analysis data for comp-1, comp-2		
Request person	#02	Counter person	#03, #11, #12
Progress	Finished	Due date	2005/10/25
Objective	Result of comp-1 and comp-2		
Contents	If you need more info, contact to me.		
File	Comp. Model. Analysis.		

Revise Delete Finish

Survay	Request No. #12		
Request person	#04	Counter person	#03, #11, #12
Progress	Finished	Due date	2005/10/21
Survey 1	What compressor is difficult operate compared to design value?		

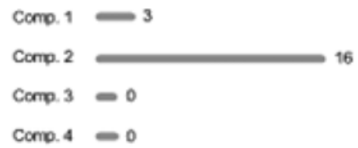

Fig. 7. Design specification: Information interaction module.

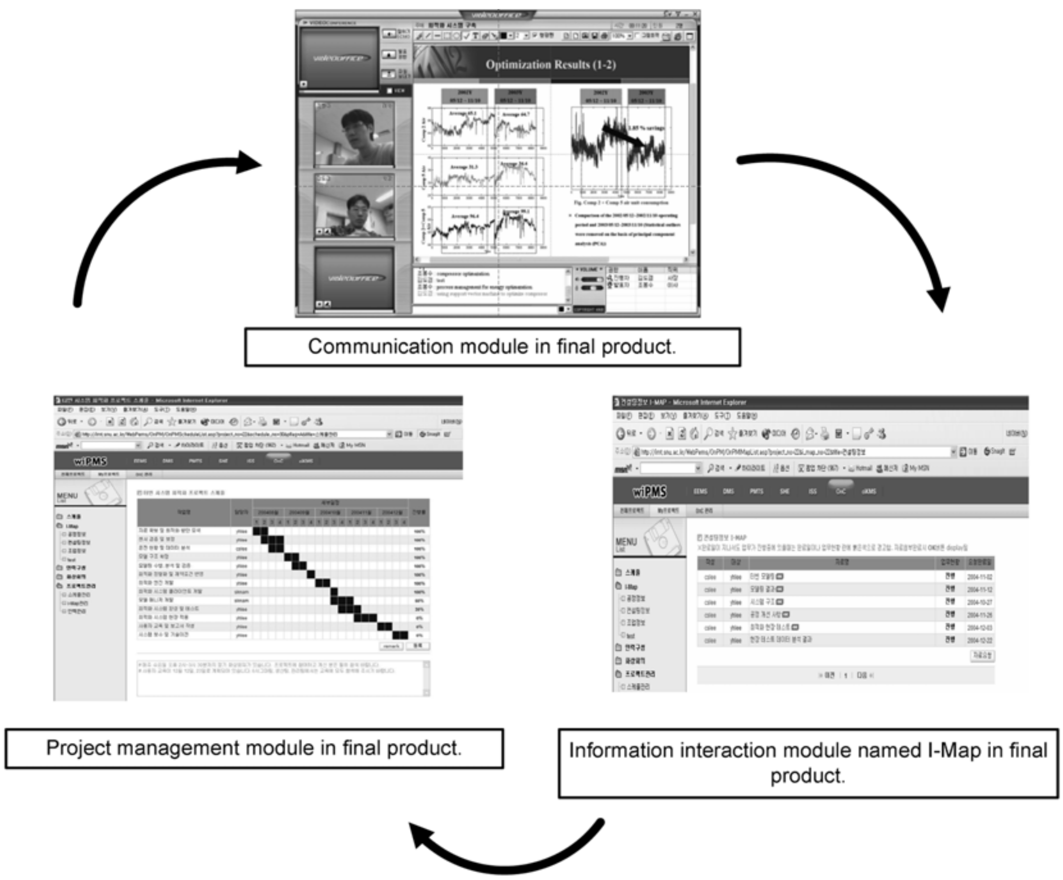

Fig. 8. Final product of Web-based online optimization system.

lem of the information interaction module limits in presentation of information.

Then, the final specification of each module is set. The programmer designs the product in more detail. Then, the final product is completed. In the communication module, the audio/video conference and the chat module are organized with the shared documents/files editing and the electronic white board in one screen. The confirming previous audio/video conference helped absent users. Also, the web-alarm can help users to notice sudden events. The project management module is constituted by Gantt chart and management of decision and change. All of these sub-modules are in one chart, so users can understand optimization process more easily. Also, the information interaction module is named I-Map, which unifies all of information and knowledge about the process. Therefore, users can collect various information and knowledge more conveniently. All of these modules are coupled. So the, weakness of each module is settled, and the synergy effect is appealing. Fig. 8 shows the use of the final product of the web-based on-line optimization system.

CASE STUDY: PLANT-WIDE COMPRESSOR NETWORK OPTIMIZATION OF THE TPA PROCESS PROJECT

The final prototype of the web-based support system for on-line optimization is developed. For evaluation of the final prototype, the plant-wide compressor network optimization of the TPA process project was selected as a case [15,16]. Since most of the electric power had been consumed in the compressor network, its optimization was important to economize energy. The result of project was that electric power is saving about 7.5 kWh/TPA ton. However, it had the typical problem of the optimization project: time and cost. Therefore, a web-based support system for on-line optimization for reducing time and cost was needed.

This project takes 150 days, and the time for each step is shown at Fig. 9. We calculate the total cost of on-line optimization project without using the suggested system. The cost of labor C_l, the cost of traveling C_t, the cost of the others C_o, and the total cost of the project C_p are given by,

$$C_l = \sum_i \sum_j d_j^p c_i^l \tag{1}$$

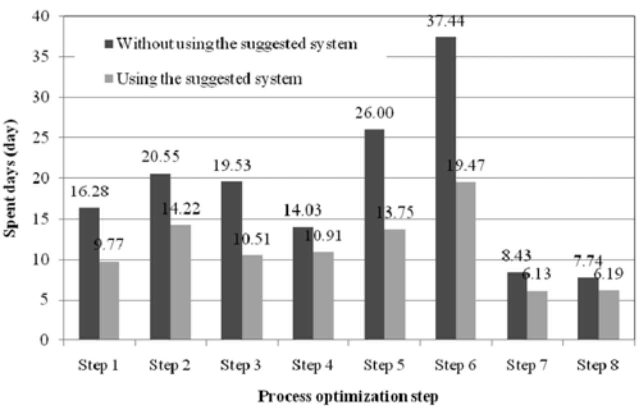

Fig. 9. Result of evaluating for suggested solution to TPA process optimization project.

$$C_t = \sum_i \sum_j d_j^t c_i^t \tag{2}$$

$$C_o = \sum_j d_j^p c^o \tag{3}$$

$$C_p = C_l + C_t + C_o \tag{4}$$

where i is index of the optimization specialists class, j is index of the project step, d_j^p is the project time for jth step, d_j^t is the traveling time for jth step, c_i^l is the labor cost per day for ith specialists, c_i^t is the traveling expenses per day for ith specialists, and c^o is the rest cost for the project per day. The result of calculation shows that $192,216 is needed to the project.

We evaluate the time and cost of the on-line optimization project using the suggested system. The reduced time of each step is shown in Fig. 9. The steps 1^{st}, 2^{nd}, 3^{rd}, 5^{th}, 6^{th} are reduced more than 30%. In the HOQ analysis, they are the main time wasting steps. It means that the developed system is effective by debottlenecking of the time consumption.

We evaluate the total cost of on-line optimization project using the suggested system. The cost of labor C_l', the cost of traveling C_t', the cost of the others C_o', and the total cost of the project C_p' are given by,

$$C_l' = \sum_i \sum_j (d_j^p - r_j^p) c_i^l \tag{5}$$

$$C_t' = \sum_i \sum_j (d_j^t - r_j^t) c_i^t \tag{6}$$

$$C_o' = \sum_j (d_j^p - r_j^p) c_i^o \tag{7}$$

$$C_p' = C_l' + C_t' + C_o' + C_a \tag{8}$$

where r_j^p is the reduced project time for jth step, r_j^t is the reduced traveling time for jth step, and C_a is the additional cost for setting of the system. The result of calculation shows that $192.000 is needed for the project. The reduced cost of each step is shown in Table 2. The result of evaluation shows that $108,704 is needed to the project carried out by the web-based support system for on-line optimization. In other words, the cost and the time of the project are reduced by 43.5% and 43.3%. This shows the outstanding effects of the system in this case.

CONCLUSIONS

A web-based support system for on-line optimization was suggested for efficient on-line optimization projects. The final product consists of three main modules: communication module, project

Table 2. Result of evaluating for suggested solution to TPA process optimization project

Cost	Without using the suggested system	Using the suggested system	Reduced percentage
Cost of labor	171,396	97,124.4	43.33%
Cost of traveling	19,020	9,210	51.58%
Cost of the others	1,800	1,020	43.33%
The additional cost	0	1,350	
Total cost	192,216	108,704	43.45%

management module and information interaction module.

The developed product is evaluated for a real-time optimization project of the TPA process. The result of evaluation is that the product can reduce both time and cost of on-line optimization projects. In other words, the product is expected to be applied to cost-effective on-line optimization projects of various chemical processes.

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NOMENCLATURE

Letters

C_l : the cost of labor without using the suggested system
C_t : the cost of traveling without using the suggested system
C_o : the cost of the others without using the suggested system
C_p : the total cost of the project without using the suggested system
C_l' : the cost of labor using the suggested system
C_t' : the cost of traveling using the suggested system
C_o' : the cost of the others using the suggested system
C_p' : the total cost of the project using the suggested system
C_a : the additional cost for setting of the system
c^l : the labor cost per day
c^t : the traveling expenses per day
c^o : the rest cost for the project per day
d^p : the project time without using the suggested system [day]
d^t : the traveling time without using the suggested system [day]
r^p : the reduced project time using the suggested system
r^t : the reduced traveling time using the suggested system

Subscripts

i : the index of the optimization specialists class
j : the index of the project step

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