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Development of a customizable web-based process analysis system for continuous process management†

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Abstract

In order to manage and control the quality of products in a real-time manner, a statistical process control methodology, one of the most popular quality control activities, is utilized as a software service in many manufacturing industries. However, these quality control systems are not affordable to small and medium sized industries due to their expense in installation, difficulty, inflexibility and lack of post management in the systems. To satisfy all the various requested given by the enterprises, we propose a customizable web-based process analysis system with user-centered design that enables continuous process management. The methodologies for constructing such a customizable web-based process analysis system are suggested first. Then, these methodologies are implanted into the suggested system, Process analysis system (PAS) and each process is described in detail. PAS is utilized in the concrete manufacturing process to observe a continuous process improvement. Lastly, the suggestions for PAS in future are discussed in this paper.

Keywords: Statistical process control; Control charts; Process analysis system; User-centered design; Small and medium-sized enterprises

1. Introduction

Quality control has become a mandatory activity in manufacturing to monitor quality of products. SPC (Statistical process control) is one of the most popular quality control methodologies as it visualizes the quality of the process graphically and numerically to facilitate monitoring the quality continuously. In the previous manufacturing environment, all the manufacturing data and the calculations had to be done manually; after several decades, most of the SPC procedures are programmed as software solutions and commercialized so that the system can find the variations in products automatically with much less effort done by users [1]. By adapting the SPC software, quality of the products will be significantly better and competitiveness of the enterprise will be enhanced as well by increase in quality of products, services and productivity [2].

Although SPC system offers a great opportunity to enhance product and quality improvement, many Small and medium-sized enterprises (SMEs) are not willing to use the system. First, the required installation cost for SPC programs is generally not affordable. Also, as an installation is generally required in these programs, the companies may face locality issues since the system can only be used in the installed computers. Second, SPC programs are solely designed for SPC experts and so are not user-oriented. Thus, beginners in SPC system may have difficulty in figuring out the role of control charts and how the system operates to achieve an appropriate result. Third, the system is usually inflexible as only few manufacturing processes are concerned overall while various cases exist in the world. Finally, once the result comes out, a post management process is necessary for continuous process improvement, while the SPC systems provide a result for a singular usage. As a result, the SPC systems cannot satisfy these requests coincidently and SMEs have been looking for other quality controlling options to enhance the quality of their products.

We suggest a process analysis system that aims to satisfy various types of request in SMEs. The system operates on a web-based framework to resolve locality and installation cost issues. Furthermore, by considering various factors in SPC systems, the system is developed to be a more flexible system. Also, the project module in the system enables the post management process, and so users can continuously monitor their process by using the suggested system. Finally, all the system procedures are simplified with user-centered designs. Thus, user-interactive elements are provided in the system to support various types of users and to comprehend the system easily. In this paper, we propose a customizable web-based system

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named Process analysis system (PAS) .

2. Related works

As the installation cost and difficulty of the SPC product have become issues in usage, some researchers agreed that web-based application could be the appropriate solution. Lee mentioned that various software tools applied for diverse process were considerably expensive and difficult so that web-based system emerged as alternative solution to use [3]. Also, if systems are able to utilize knowledge resources which are yet difficult to organize systematically, then users may access the system more easily [4, 5]. With this information, the study suggests web-based system and user-centered system through simplifying knowledge resources as two major components.

Besides the theoretical studies, there have been other researches with practical solutions. Laosiritaworn suggested a web-based SPC solution connected with a database to store the process and result data continuously [6]. In the system, the regulations for determining the stability of the process are suggested as well. Ab Rahman et al. proposed another web-based SPC solution which could be favored in SMEs [7]. The system is developed within a project module to store the process data and result securely and present a possibility to manage the process continuously. Lee demonstrated a web-based and knowledge-based SPC framework named KBAS (Knowledge-based analysis system) [8]. Lee aimed to reduce cognitive process in the previous SPC systems by collecting knowledge resources and utilizing them to facilitate several produces in the SPC systems.

The practical researches had shown efforts to reduce cognitive process and installation cost faced by SMEs. However, in order to construct a more customizable process analysis system, flexibility and post management process must be considered as well. In the next section, the methodology to construct such a customizable system is proposed.

3. The methodologies to construct a customizable system

3.1 Simplification of analysis cases

To propose a customizable SPC solution, there are several elements to be considered. First, analysis cases must be integrated for enabling analysis in various perspectives. The major analysis options in SPC solution are control charts. In each chart, the statistical method and the purpose will be different. Most of the similar solutions are limited to presenting a singular result by choosing one of the control charts. Furthermore, there could be a redundant process for analyzing several control charts with the same process condition. The suggested system is supposed to provide several results in a singular analysis. Thus, several charts can be selected at once while all the redundant processes should be reduced as much as possible. By collecting similarity and difference in each control chart, the redundant process can be combined while specific process can be represented as a unique requirement. For instance, the difference between Xbar-R chart and cumulative sum (CUSUM) chart is the sensitivity in measuring variation of the manufactured products. Generally, Xbar-R is sufficient to measure the variation on the graph; however, in some cases, the result from Xbar-R and CUSUM will be different since the CUSUM chart measures variation much more carefully than Xbar-R chart. If these charts are shown together, then the analysis result will represent various types of measurements at once. Thus, utilizing various charts at once is crucial to validate whether the process data is acceptable in all of the experiments.

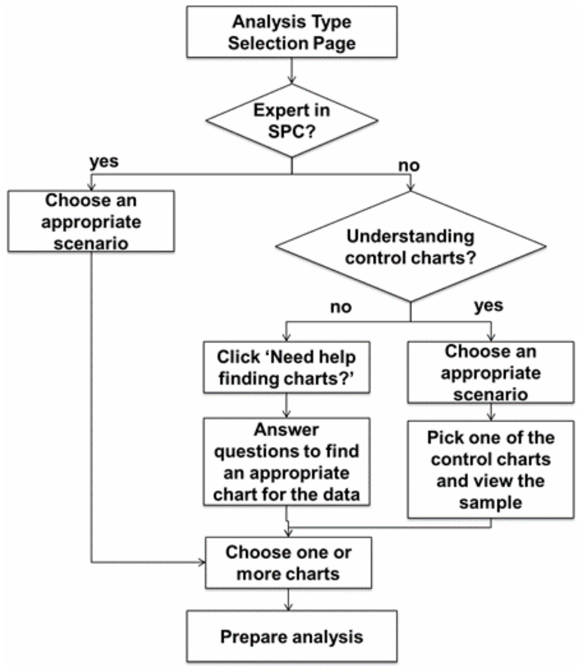

Fig. 1. The guide system for various users in the suggested system.

3.2 A user distribution determined by SPC knowledge

Users are a vital component in the SPC system, as simplicity is one of the most important requests. At the same time, distributing users into several levels is important since the efficient step for each user may be significantly different. Thus, users are distributed into three distinct levels by considering control chart usage and process characteristics.

The users who only understand process characteristics are determined as level 1 users, and they are suggested with the guide option provided in the system. The guide option asks questions that determine the corresponding control chart with chosen process characteristics. These questions are based on the distribution of the control chart suggested by Montgomery [9]. The users who understand some of the control charts are level 2 users and supported with the sample result to observe how the specific charts can be utilized. Lastly, the experts are supported with the fastest way to approach the result. Each corresponding path for the type of users is described in Fig. 1.

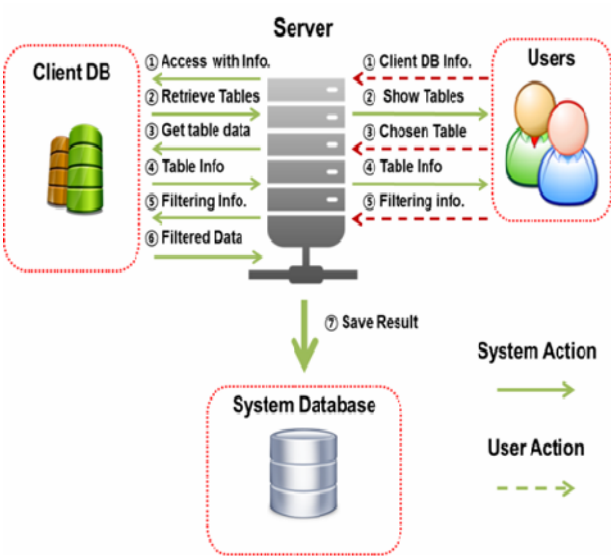

Fig. 2. The database connection system of the new KBAS.

3.3 A data compatible system

To construct a data compatible system, there are three concerns: The size of data, the way to filter data, and types of data. These concerns must be capable of being customized in various conditions so that the system can be named as a customizable solution.

First, the suggested system should store large size of data since there can be more than thousands of process data. To store such a huge size of data, Java script object notation (JSON) is recommended to serialize large size of data into a singular line and Character large object (CLOB) is suggested for storing JSON into the system database.

Since huge amounts of data can be stored into the system, the filtering methodology for such data should be considered as well. Hence, a horizontal scroll bar is suggested for managing the rows of data and each column from the data table can be chosen for filtering the size of columns of the data. The data filtering procedure is described in detail in Fig. 2. Lastly, by observing the most frequently used database and file formats in both Korea and United States, the standard databases and the file formats, namely, Excel, Text and CSV, are chosen as the allowable data formats in the system.

3.4 Determination of accessible browsers

The standard browsers for the system must be determined. Since there are various types of browsers, each browser has a distinct characteristic in demonstrating the interface. In other words, the system can be demonstrated differently, although the system shares the same server and client languages in each browser. Thus, the most frequently used browsers from 2011 to 2013 in Korea and United States are analyzed. As a result, Chrome, Internet Explorer and Safari were chosen as the accessible browsers for the suggested system.

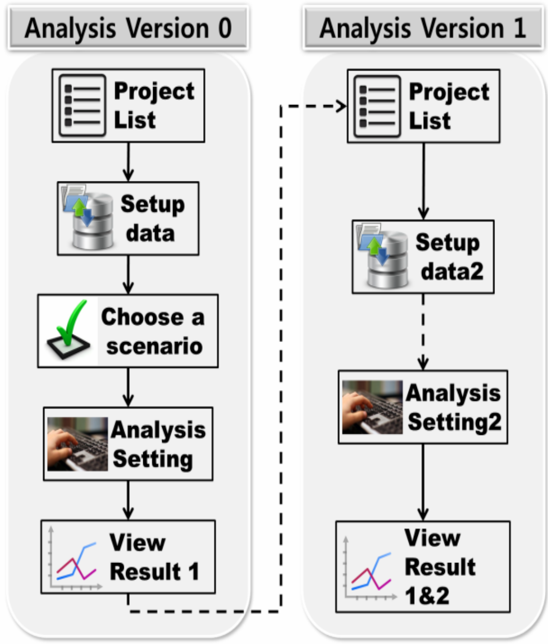

Fig. 3. Project-based procedures in the suggested system.

3.5 Systemization of continuous analysis procedure

One of the main objectives in this paper is to suggest a method to construct a process analysis system for continuous process improvement. Thus, the system must be capable of managing not only the previous result, but also results created in the future. As a corresponding solution, a project-based solution is suggested. The project-based system can enable the post management process by allowing users to save the information into a specific project and update the newly produced data into the project continuously. Furthermore, other SPC systems suggest a main framework that provides a tool bar to select analysis options; the main interface will not change while there will be various new windows on the interface to support the corresponding options. Such a framework is inefficient for certain users since they are new to the systems and they may not know where to commence. As a consequence, we suggest a framework with five distinct steps: Project lists, setup data, choose a scenario, analysis setting, and view result. By connecting these steps within a project-based system, the system can store information from each step and integrate them to create an analysis version. First version is numbered as 0 and it requires all the five steps. At the same time, on the additional versions, redundant tasks can be found and they may delay the time for the whole process. Particularly, steps named ‘choose a scenario’ and ‘analysis setting’ are the redundant tasks. Thus, the suggested system should remove a ‘choose a scenario’ step and provide an ‘analysis setting’ step as an optional task as shown in Fig. 3.

4. Implementation of a process analysis system

Based on the methodology and the related technology in the

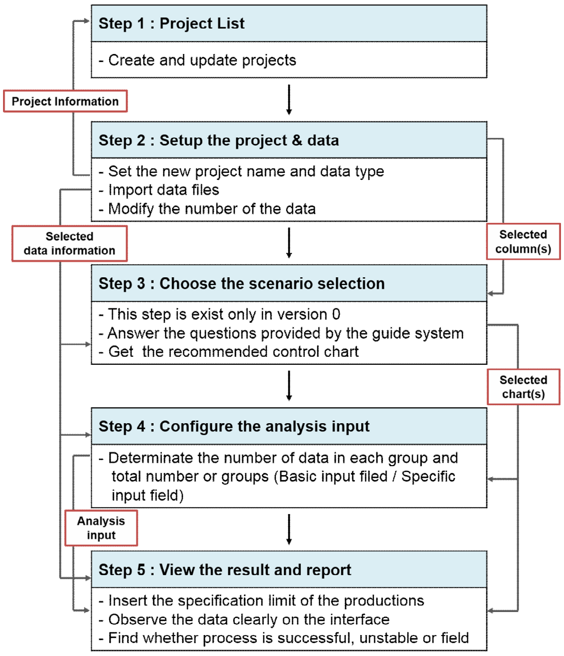

Fig. 4. The distribution diagram about PAS system.

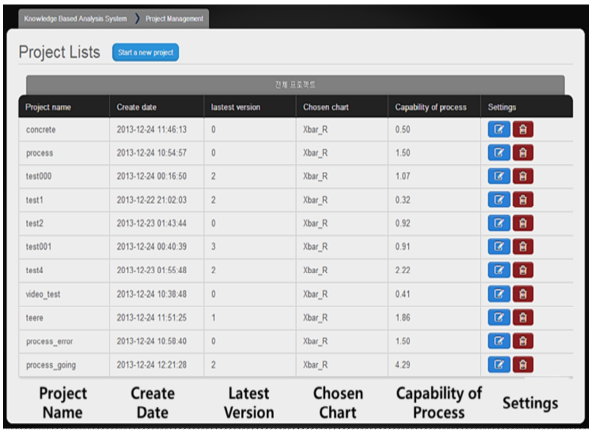

Fig. 5. A project list step in PAS.

previous sections, the suggested system, named PAS, is constructed. As mentioned, there are five main steps in the system: project list, setup data, choose a scenario, analysis setting, and result. The distribution diagram about PAS system is demonstrated in Fig. 4. The first step is a project list step where users can manage the previously created projects and update them if necessary. In the project information table, there are project name, create data, latest version, chosen control chart, and capability of process in the latest version given as the basic information. If users want to edit, create or check projects in detail, a column named "settings" provides editing and deleting options for the project. An interface of the project list step is demonstrated in Fig. 5.

The second step is the project and data configuration step. In this step, the new project name and data type can be configured at first. If the chosen data format is one of the databases, then all the database information must be inserted and the system will attempt to connect into the database. If the chosen data format is a file format provided in the system, then users should import their files and corresponding first 100 samples inside the file will be shown as demonstrated in Fig. 6. After data selection, users can modify the number of the data they want to put on the experiment. By using a horizontal scroll bar shown in Fig. 7, users can modify the numbers of rows of the data. Also, there are two options for the columns: single or plural. If singular column is chosen, then only one column can be chosen from the data table. After filtering a row size and a column size, users will be able to check the data for the experiment and they can move onto the next step.

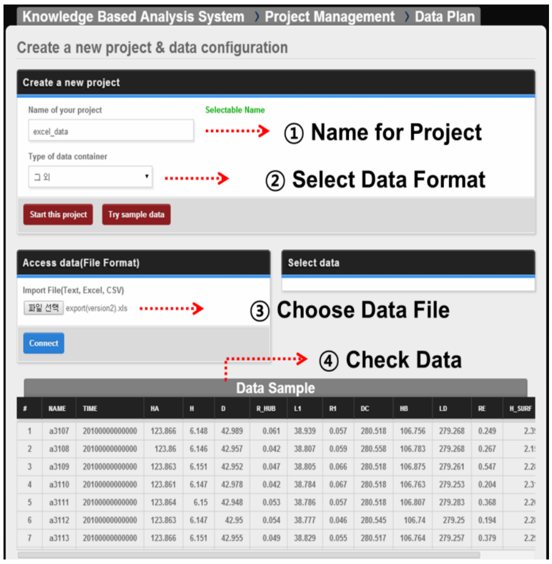

Fig. 6. Project creation and database information insert process in PAS.

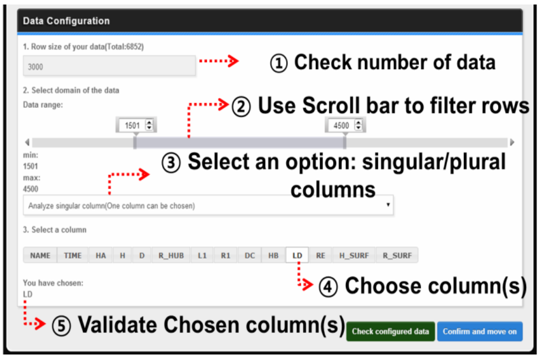

Fig. 7. Data configuring procedures in PAS.

The third step is the scenario selection step that allows users to choose an appropriate scenario and a corresponding control chart. The sample result will be provided automatically as users choose a specific chart as demonstrated in Fig. 8. Furthermore, if users cannot recognize which scenarios and control charts are proper, then a guide system that asks users questions related to the process characteristics is provided.

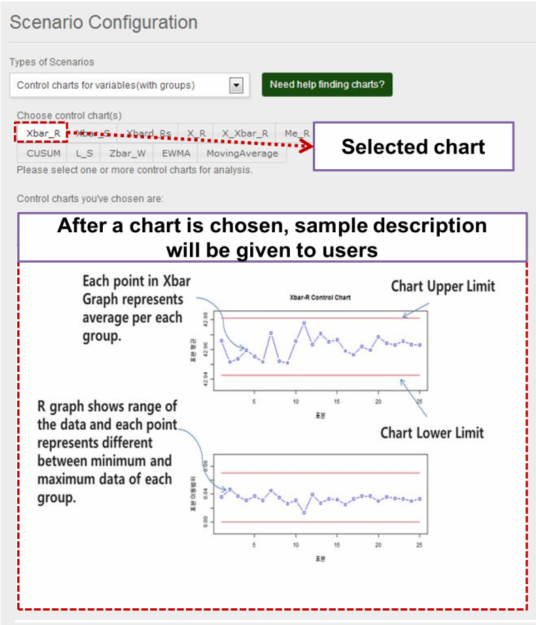

Fig. 8. A scenario selection process in PAS.

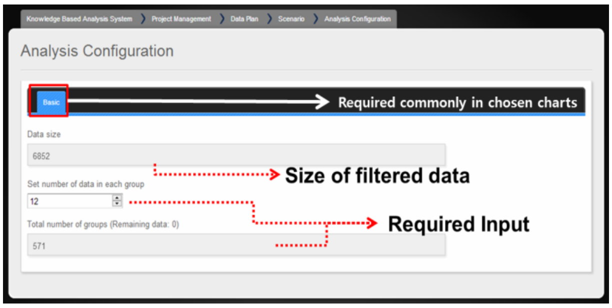

Fig. 9. A basic input field in an analysis preparation step.

Fig. 10. Specific input fields in an analysis preparation step.

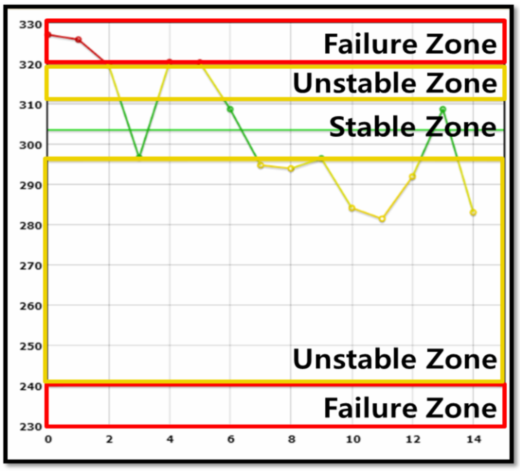

Fig. 11. Determination of the process condition based on the specified limits.

After answering all the questions, the recommended control chart will be given on the interface. To reduce redundant procedure, once the scenario is first chosen in version 0, it will be fixed on the following versions. Thus, if the version is greater than 0, the scenario selection step will be skipped and users will be moved onto the fourth step automatically.

On the fourth step, an analysis setting step, the required inputs for chosen charts will be requested to users as shown in Figs. 9 and 10. If users choose more than one chart, the system will integrate common required fields for the chosen charts and set them as basic inputs as mentioned in Sec. 3.1; the rest will be given as a specific field for certain control charts. For instance, if users choose Xbar-R, Zbar-W and moving average from the scenario step, then the number of the data in each group must be the same. Therefore, the data per group will be given as a basic input. Furthermore, Zbar-W and moving average have specific inputs, expected value and weight for sensitivity, respectively. The specifically required inputs will be provided with the name of the control chart as shown in Fig. 10. These analysis steps will be provided when the new versions of the projects are formed. However, the system highly recommends using the same inputs since it will make a big difference in integrating the result data.

The last step is the result and report step. On the result section, the statistical result based on chosen data, scenario and inputs will be provided on the interface. Furthermore, various interaction elements such as zooming in and out are provided to observe the data clearly on the interface. Once users are ready to check the report, they must insert the specification limit of the productions which will be used for finding defects in the process. On the report section, users may find whether process is successful, unstable or failed as shown in Fig. 11.

There are two main factors determining the process condition: product specification limits and control chart limits. The product specification limits are applied to demonstrate whether defect data exists. At the same time, corresponding limits from the chosen control charts are given on the same graph to demonstrate whether the process has unstable data that can be shifted into defects. In addition, these unstable and failure data are recorded on the annotation field so that users can specify the particular causes of these erroneous data. A histogram of the data is provided to check the distribution of the process as shown in Fig. 12; based on this information, process capability is calculated. After saving the project, users can access it from the project list page and can update the newly produced data. These data can also be aggregated so that users can view how

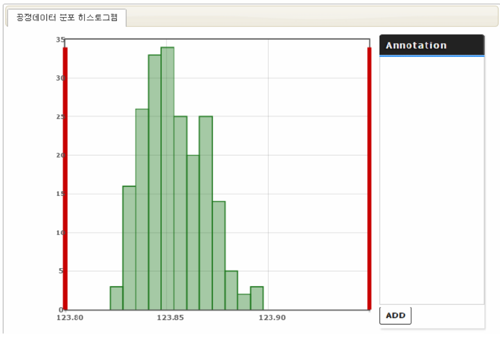

Fig. 12. The distribution histogram of PAS system.

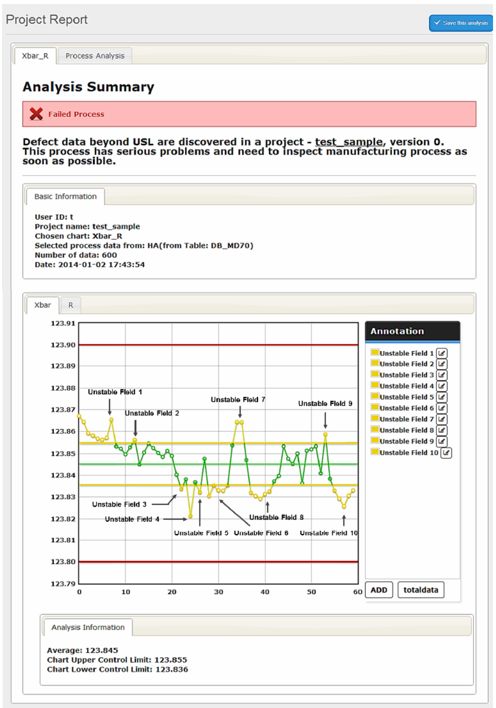

Fig. 13. The whole demonstration of a report section.

the process changes from a first attempt. The whole functions of a result step are given on Fig. 13.

5. Application of PAS

Concrete specimens were chosen as the samples for validating PAS as a quality controlling tool. The data to be used in the study is the strength obtained through compression test of concrete specimens. The expected value of the specimen is 240 kg/cm^3 and it is assumed that ten specimens are produced daily. Since the sample cannoy be reused after being used once, the experiment is quite expensive; thus, ten specimens are reasonable enough to be used as experimental results. The total number of data in the database is 150 collected over 50 days. To apply PAS in a concrete manufacturing process, all the constraints in the process are first analyzed and a proper control chart is determined correspondingly. The new project name was set to "concrete test". The number of data per group

Fig. 14. The cumulated concrete process data from the three consecutive experiments.

was determined to be ten. The upper and lower specification limits for the data were set as 320 kg/cm^3 and 240 kg/cm^3, respectively. Xbar-R was chosen as the control chart. That is why there are ten data per group and datasets can be grouped. In the first experiment, there were several defects that exceeded all of the boundary limits. PAS strongly warned users to improve the process and update the newly produced data to check the improvement. In the second experiment, the process condition had changed to an unstable process since some of the data were beyond the control limits. Thus, process improvement was still suggested. The process became a successful one at the third project. Even though the improvement process was still relying on the users, PAS aimed to inform the process condition in various options and enable users to save these reports continuously to check the cumulative condition of the process as shown in Fig. 14. The report provides three isolated concrete data on the same graph, so users can observe the change of the dataset distribution reflecting the result of the modification of the process condition.

6. Conclusion

The major objective in making the SPC system affordable to SMEs is reduction of the installation cost and complexity. Flexibility and post management process should also be considered in order to create a customizable process analysis system. We considered these factors together and combined them into a methodology for constructing a customizable system. Analysis cases, users, data, browsers and analysis procedures are considered as the most influential factors. Once the methodologies are set, they are implemented into the system named PAS with five distinct steps: Project list, setup data, choose a scenario, analysis setting and result. Since the system has project modules, the resultant data can be reused in the next experiment. Thus, the system can be applied continuously to observe previous, current and further conditions by enabling cumulating data on the same graph. After implementation, PAS is applied to a concrete manufacturing process to analyze condition of the process. Also, the continuous improvement after observing the condition is demonstrated and recorded so that PAS can be utilized for analyzing process changes as well.

There are several suggestions that can enhance the system in various fields and conditions. First, it has been found that even if the system can allow thousands of data on the graphical interface, the interface has a limit of size to demonstrate these points in detail. At the same time, widening the interface is not suggested. Thus, the method for summarizing thousands of points on a graph should be considered. The system should be provided a linear regression methodology since it will reduce the size significantly by summarizing the relationship among the points by a linear line. However, it may neglect several points when they cannot be considered into the relationship. Therefore, the usage of a linear regression must be considered in many perspectives. Furthermore, applications of the process analysis system can be enlarged with many types of industries. Indeed, there are various researches in health and chemistry fields regarding SPC systems as well [10, 11]. Consequently, in order to make the process analysis system customizable with various fields, the related knowledge must be learned and stored into the system.

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