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Design of an Energy and Maintenance System User Interface for Building Occupants

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ABSTRACT

In this paper, we describe the design of a user interface for energy and maintenance systems in commercial buildings. The user interface is designed for use by occupants (tenants) of commercial buildings. Our hypothesis is that by allowing tenants access to information from the energy and maintenance systems and by giving them some control over these systems, energy and maintenance performance can be improved. We used interviews with potential users and existing energy and maintenance databases to guide the design. We found that the feature most important to occupants is the ability to track service requests. We included several features from the interviews that should improve occupant satisfaction with maintenance and operations and simultaneously improve operational efficiency. We show results of implementing the user interface in two government office buildings.

INTRODUCTION

Energy and maintenance systems in commercial buildings consist of digital control devices, a communications network, databases, applications for various functions, and a user interface. One of the most advanced energy and maintenance systems developed to date is GEMNet (Piette et al. 2002). GEMNet is an integrated information technology infrastructure for energy and maintenance management. It uses a common database system for all components and an open communications protocol called BACnet® (ASHRAE 2001).

GEMNet uses modern web-based technology for its user interface. However, the intended users of GEMNet only include maintenance personnel. The way that building occupants interact with GEMNet is by making a telephone call to someone in the maintenance department to request service or

report a problem. The maintenance personnel manually enter the service request into GEMNet, sometimes long after the phone call has been made.

Our work on the interaction between building occupants and energy and maintenance systems (Federspiel 1998, 2001) suggests that building occupants should also be considered users of energy and maintenance systems. Until recently, this has been considered an unwise, even radical, idea among facility management professionals. However, providing tenants with a user interface to energy and maintenance systems should improve thermal comfort, improve the performance of energy management strategies, eliminate some redundant service requests, and improve the quality of data in maintenance databases. A well-designed user interface should also improve the satisfaction of the occupants with the services provided to them by maintenance personnel.

In this paper we describe the design of a tenant user interface for energy and maintenance systems. The user interface is designed to operate as a component of GEMNet. The next section covers the methods we used for design. The following section includes the results of our predesign investigations, a description of the design itself, and results of a field trial.

METHODS

We used three sources of information to guide the design of the user interface: interviews with tenants, meetings with maintenance personnel, and historical maintenance records.

We interviewed three potential users from three different tenants in a U.S. federal building. Tenants are defined as organizations or agencies occupying the building. The occupants who we selected were chosen because they are one of the persons who their organization has selected to be a primary

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point of contact for reporting building-related problems to the maintenance organization. This fact means that they have considerable experience with maintenance activities and that they are likely to use the user interface frequently. Not all tenants have selected individuals to be points of contact for maintenance issues. Occasionally individuals other than one of the primary points of contact report service requests to the maintenance organization.

We asked questions designed to provide information about how the problem-reporting process currently works, their satisfaction with the current process, their needs for changes, and whether or not they would be receptive to our proposed design ideas. The interviews were conducted in person. The operations manager was present for one of the three interviews. We did not use the interviews to help us with the layout of the user interface. A copy of the interview questions is listed in the appendix.

We held five meetings with the building energy and maintenance staff to discuss our concepts for the design of the user interface. These meetings included the area manager, the operations manager, the GEMNet program manager, the software engineer who developed the GEMNet code, and a few other maintenance personnel who worked for the operations manager or the GEMNet program manager. Not all of these people attended every meeting. We described our previous research results, proposed our design for the user interface, and asked for their feedback.

Federspiel (1998, 2001) analyzed maintenance records from hundreds of buildings, covering a duration of several years in total. His analysis shows that 75% of environmental complaints reported by occupants and recorded in maintenance databases involve thermal conditions (too hot or too cold). Taken together, thermal complaints are the most common kind of service request from occupants. In well-controlled buildings, about half of these complaints occur when the temperature is within the comfort zone defined by ASHRAE (1992). We used these findings to guide the design of the user interface.

To test the user interface, we implemented the user interface in two buildings. One building was 100,000 ft², and the other was 400,000 ft². We recruited three lead users from three different tenants of these two buildings. The lead users were recruited for the same reasons used to recruit the occupants who we interviewed. The lead users were not the same as the occupants who we interviewed, and the field trial was not conducted in the same building as the interviews. To assess the impact of the user interface, we tracked service requests submitted through the user interface and by phone before and after the user interface was deployed. All service requests reported through the user interface were automatically entered into the maintenance database and flagged as originating from the user interface. Service requests submitted by phone were entered into the maintenance database by hand, so it is possible that some service requests submitted by phone were not recorded. However, there is no reason to suspect that the frac-

tion of missing phone requests changed after deploying the user interface. We asked the lead user who used the user interface most for feedback about its design.

We used the statistical test described in Fleiss (1981) for comparing two Poisson parameters to test whether or not there is evidence that the service request rate after deploying the user interface is different from the service request rate prior to deploying it. The null hypothesis for this test is that the arrival rates are equal. The test statistic is as follows:

$$s = \frac{\left| \frac{k_A}{k_A + k_B} - \frac{T_A}{T_A + T_B} \right| - \frac{1}{2(k_A + k_B)}}{\sqrt{\frac{\frac{T_A}{T_A + T_B} \left(1 - \frac{T_A}{T_A + T_B} \right)}{k_A + k_B}}}$$

where k_A is the number of service requests prior to deploying the user interface, k_B is the number of service requests after deploying the user interface, T_A is the duration over which service requests were counted prior to deploying the user interface, and T_B is the duration over which service requests were counted after deploying the user interface. Under the null hypothesis, s is approximately standard normal.

RESULTS

Interviews and Predesign Analysis

From the interviews with tenants, we learned the following:

1. All tenants currently report service requests by telephone. Office assistants usually report problems on behalf of others.
2. The average satisfaction level with the reporting process was two on a scale of one to five, with one being the most satisfied and five the least satisfied.
3. All tenants complained about not being able to track the status of service requests. Some tenants would prefer to check status at a web site, while others would like to receive e-mail. Some tenants want to be able to check indoor temperatures from a browser, and some tenants would like to be able to access maintenance notices from a browser or by e-mail.
4. Tenants sometimes submit more than one service request for the same problem because they cannot track the status of their service requests and because they think it will reduce the response time.
5. Two of the tenants surveyed said they would use a web-based service request form.
6. One of the tenants said that they would be more likely to report problems if it were easier to report them.

Maintenance personnel told us that it is common for maintenance or construction activities to produce many redundant service requests. The information that they

provided was anecdotal, but it was supported by data in maintenance databases. For example, in maintenance databases we analyzed, we found “clusters” of thermal complaints that were related to shutting down air-handling equipment for maintenance purposes and for construction purposes. The information provided by the maintenance personnel reinforced our concept of including a mechanism for the operations manager to post messages to the user interface informing occupants of activities such as maintenance or construction.

From results in Federspiel (1998, 2001) and from maintenance databases that we analyzed, we learned the following:

- Temperature complaints are the most common service request.
- In well-controlled buildings, half of the temperature complaints occur when the temperature is within the bounds specified by ASHRAE (1992).
- Data quality in maintenance databases is poor. Most of the fields are populated by hand, and service requests are relayed between two or three people before they are entered in the database.

Design

Based on these findings, we included four key features in the user interface. The first is the ability to check the status of service requests. Users can check the status of all service requests they submitted and filter the display by status condition. We did not originally plan to include this feature in the user interface, but it was clear from the interviews that this is one of the primary needs of the occupants.

The second feature checks for service requests submitted from the same location during the past two hours and displays them when a service request is submitted. The design intent is to eliminate redundant service requests. The user interface does not prevent the user from submitting the request because it is possible that a second service request will contain important information about a problem that was not contained in the first service request.

The third feature of the user interface is a list of notices that the maintenance personnel feel will convey useful information to the tenants. Tenants only see notices that apply to their location. Maintenance personnel can specify the length of time that the notices run.

The fourth important feature of the user interface is the ability to check indoor temperatures. This feature is made possible and relatively simple by the fact that GEMNet control devices communicate using an open protocol called BACnet®. GEMNet polls thermostats every five minutes and places the data in a circular buffer. The user interface displays the most recent temperature value from the GEMNet database corresponding to the location specified by the user. Users choose a default location that becomes part of their profile. If temperature data are available, then the user interface shows users the temperature at the complaint location when they submit a service request.

Figure 1 shows a site diagram of the user interface. The solid lines show links between pages. The dashed boxes show sets of related pages. The features described above are distributed throughout the user interface. For example, when a tenant logs in, he or she is immediately shown a table of service requests previously submitted, and the temperature for their default location is shown in a sidebar. Figure 2 shows the home page, and Figures 2 through 8 show screen shots of different pages that make up the user interface.

Field Trial

We trained the lead users and the operations manager how to use the user interface in mid-September of 2002, and they started using it in October. Figure 9 shows the number of service requests submitted to the maintenance organization by three of the lead users. The other lead users did not submit any service requests through the user interface. One of the three lead users shown here only submitted one of nine service requests through the user interface during the October-December time period. Prior to February 2002, service requests were not recorded in the maintenance database, so no data are available prior to February 2002.

The number of service requests increases throughout the year, possibly the result of a learning curve on the part of the maintenance personnel responsible for recording service requests. The figure demonstrates that some occupants will use the web-based user interface for a significant fraction of service requests, eliminating the labor required to answer phone requests.

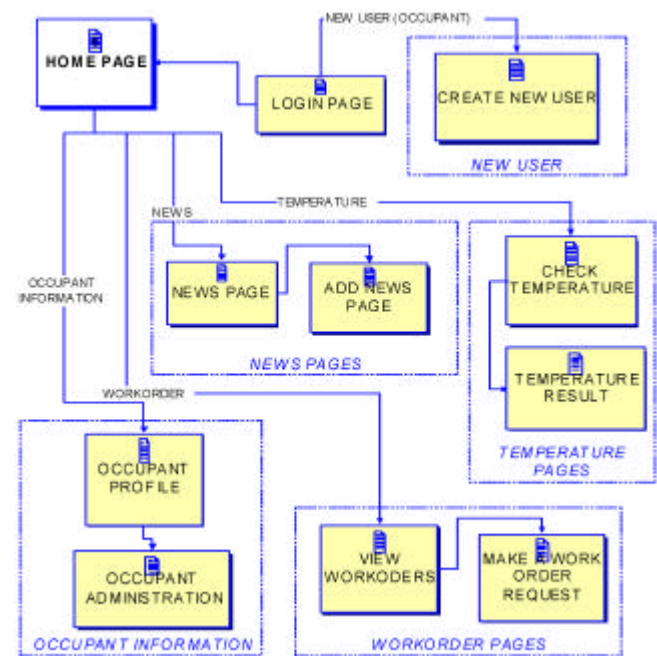


Figure 1 Site diagram of the user interface.



Welcome to GSA's Tenant Interface for GEMNet Portal
 Through this portal you can:

- Read important building [news](#)
- Submit and view [Service Request](#) information.
- Get a glimpse of the outside [weather](#).

All news Headlines

[\(View all News\)](#)

Last 10 Service Requests	Date Reported On	Status
the urinal on the northwest side of the mens restroom is running. The water is not over flowing a contant running. Location in inside 4800	2/4/2003	In Progress
clogged drain in eastside kitchen near rm 4846	1/31/2003	Completed
Bugs!! please spray.	1/30/2003	Closed
please turn the fan back on in room 3730	1/22/2003	Completed
There is a burnt smell in the stair well at door 3730 between the 3rd and 4th floor.	1/22/2003	Completed
I called this in already but rm 3730 has no air flow. Please check.	1/17/2003	Completed
room 4868 file cabinet drawer is stuck again.	1/17/2003	Closed
room 3725 is frozen will please give her some heat?	1/13/2003	Closed
it a freezed out in room 3734.	1/10/2003	Closed
in room 4801 it is too cold. Mr Cool that would be my room. Vent is blowing out cold air above me. I've been out with the flu for days please help.	1/10/2003	Closed

[\(View all Service Requests\)](#)

Figure 2 Home page of the user interface.

[Logout](#)

[Home](#) | [News & Weather](#) | [Service Request](#) | [Profile](#)

| [View Profile](#) | [Edit Profile](#) | [View all Profiles](#) |

Edit Profile:
 Please update personal and location information.

- Personal information allows for service requests to be correctly submitted.

Edit Profile Information

Personal Information

First Name:

Last Name:

Work Phone:

Change Password

Enter your NEW Password:

Confirm your NEW Password:

Figure 3 Page used to edit personal profile.

The screenshot shows the GSA Service Request page. At the top, there is a GSA logo and the text "U.S. General Services Administration". Below this is a navigation bar with links for "Home", "News & Weather", "Service Request", and "Profile". A "Logout" link is also present. Below the navigation bar, there are links for "View Open Service Requests" and "Create a New Service Request".

The main content area is titled "Service Request Log:" and includes a brief explanation: "This is a list of service requests that you have submitted." Below this, there is a list of instructions for users:

- **Service Request Number** is a unique number used to track service request.
- **Description** of the service request issue.
- **Reported On**, date service request entered.
- **Status** is an updated standing of the service request. Under review while pending. Please wait for status update.
- [Enter a new service request](#)

To the right, there is a section titled "Your Service Requests (53)". It includes a filter box with options: "Closed", "Completed", "In Progress", and "View all service requests". Below the filter is a table of service requests:

Service Request No.	Description	Date Reported On	Status
71972	the urinal on the northwest side of the mens restroom is running. The water is not over flowing a constant running. Location in inside 4600	2/4/2003 2:31:02 PM	In Progress
70832	clogged drain in eastside kitchen near rm 4846	1/31/2003 8:49:44 AM	Completed
70364	Bug!! please spray.	1/30/2003 8:16:13 AM	Closed
69355	please turn the fan back on in room 3730	1/22/2003 1:11:12 PM	Completed
69353	There is a burnt smell in the stairwell at door 3730 between the 3rd and 4th floor.	1/22/2003 1:09:13 PM	Completed
68673	I called this in already but rm 3730 has no air flow. Please check. natalie	1/17/2003 1:12:50 PM	Completed
68750	room 4858 file cabinet drawer is stuck again.	1/17/2003 7:27:54 AM	Closed
68073	room 3725 is frozen will please give her some heat? Natalie	1/13/2003 10:14:40 AM	Closed
67889	it a frozen out in room 3734.	1/10/2003	Closed

Figure 4 Page used to view previously submitted service requests.

The screenshot shows the GSA New Service Request page. At the top, there is a GSA logo and the text "U.S. General Services Administration". Below this is a navigation bar with links for "Home", "News & Weather", "Service Request", and "Profile". A "Logout" link is also present. Below the navigation bar, there are links for "View Open Service Requests" and "Create a New Service Request".

The main content area is titled "New Service Request Instructions:" and includes a brief explanation: "Please read these instructions before entering a new service request". Below this, there is a list of instructions:

1. Ensure local temperature is within GSA policy.
2. Check that required fields(*) are updated and accurate.
3. Enter or select the floor for which the problem is being reported for.
4. Select the problem type that best describes this service request.
5. After completing these steps, continue to the next form.
6. Please do not submit multiple service requests for the same issue.

To the right, there is a form titled "Step 1. Ensure the local temperature is within GSA policy". The form includes the following text: "The acceptable temperature range is 70°F to 77°F according to GSA Energy Policy". Below this, there is a section titled "Step 2. Verify Contact Information and Select Problem Type". The form includes the following text: "Please verify that the information in this form is accurate and up to date. * Fields can be changed by updating Profile". Below this, there is a section titled "Step 3. Select Affected Floor and Problem type". The form includes the following text: "Please select the floor for which the service request is being reported for. Then, select the type that best describes the problem. If not listed, select other." Below this, there is a form with the following fields: "Type impacted floor: (i.e. *02.03*)" and "Problem Type: Please Select". Below the form, there are "Continue" and "Cancel" buttons.

Figure 5 First page used to submit a new service request. Many service requests involve temperature problems, so the user interface shows the indoor temperature and the policy for indoor temperature.

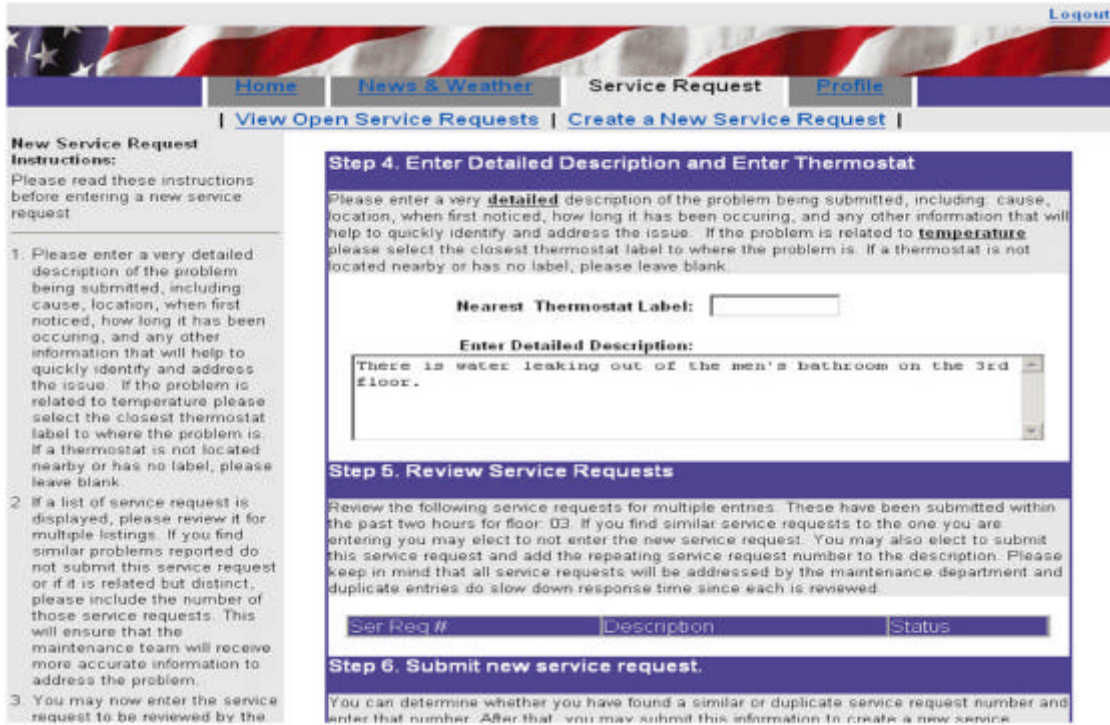


Figure 6 Second page used to submit a new service request. The user interface informs users of previously submitted service requests that may be similar to this service request.

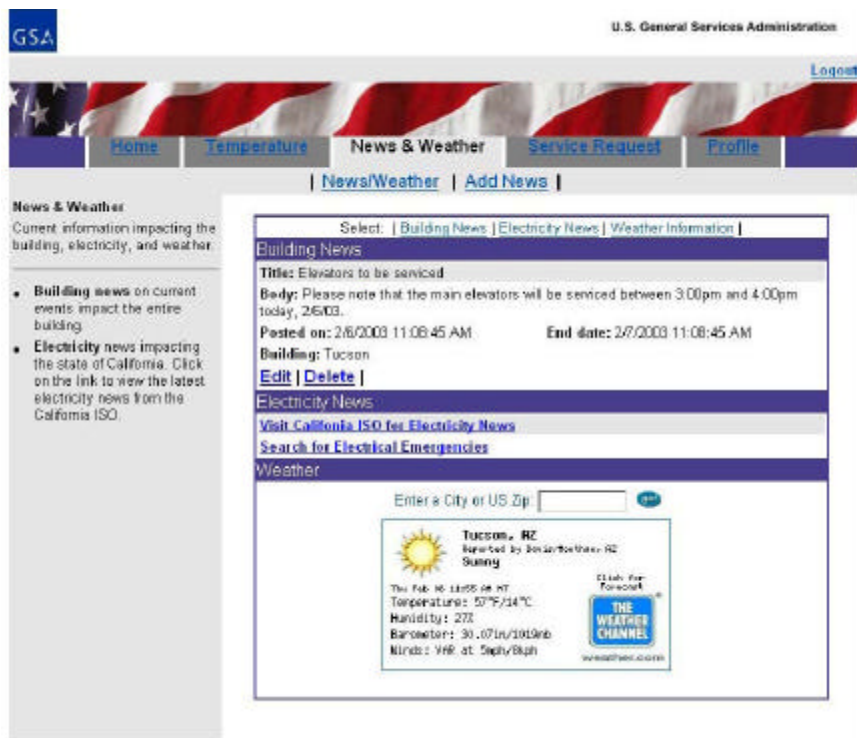


Figure 7 Page used to check news and weather. Notices on this page can only be deleted by the administrator.

GSA U.S. General Services Administration [Logout](#)

[Home](#) [Temperature](#) [News & Weather](#) [Service Request](#) [Profile](#)

Temperature
 In this page you can view the temperature for your default thermostat or set a default thermostat or set a default thermostat.

- **Default Thermostat** provides the latest temperature of your default thermostat. Your default thermostat is stored in your [profile](#). In order to set a default thermostat follow the next steps:
- To **Set** a thermostat as the default in your profile or **Find** a thermostat in the building you need to:
 1. Select a **Floor**.
 2. Select the nearest **Thermostat** closest to you by reading the label on it.
 3. The **Temperature** information will be displayed. In order to select this thermostat as the default in your profile, click on the button.

Closest Thermostat (5E-13) Temperature Last modified: 5/4/2002 12:59:09 PM

72 °F / 23 °C (Last modified: 5/4/2002 12:59:09 PM)

Set or Find closest thermostat temperature

Step 1. Select Your Floor

Step 2. Select the nearest thermostat label

Step 3. After selecting the floor and thermostat, the temperature will be displayed below.

The temperature at thermostat label 5E-13 is 72°F / 23°C
 It was last updated on: 5/4/2002 12:59:09 PM

Click on the button below to set 5E-13 as your default thermostat.

Figure 8 Page used to check indoor temperature. This page causes the user interface to query the GEMNet database for the most recent reading at the specified location and to display it in the browser. This page gives the user the option to change the default location.

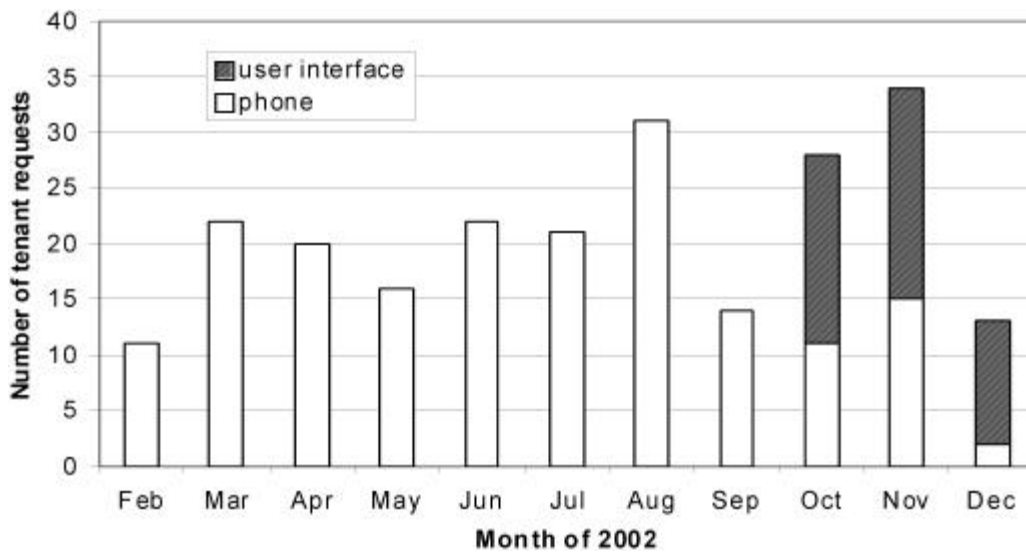


Figure 9 Number of service requests submitted by a lead user.

TABLE 1
Service Request Rate Comparison

Duration	Counts	Req/Month	s
Jul-Sept 2002 (3 months)	66	22	0.67
Oct-Dec 2002 (3 months)	75	25	

Table 1 shows the results of testing the hypothesis that the service request rate from these lead users was the same before the user interface was deployed as it was after. We compared the three-month post-deployment period with the three months prior to deployment because of the increasing trend in the predeployment interval. The probability of observing a larger test statistic by chance is 25%, so we conclude that the difference is not statistically significant.

We asked the most prolific user to provide feedback on the user interface. She said “I love the system,” but she had critical comments about the design of the profile pages.

Although the operations managers told us that they thought the notice-posting feature would be useful, we found that they did not use it.

DISCUSSION AND CONCLUSIONS

The results of the field trial illustrate several important points. The first is that some occupants will make significant use of a web-based interface for reporting and tracking service requests. This fact implies that the user interface could reduce the labor required to answer phone calls for service requests. It also implies that the user interface can improve the quality of data in a maintenance database because all of the information reported through the user interface is automatically entered into the maintenance database.

Another important point is that even the most prolific lead users sometimes still need to use the telephone to report service requests. Some service requests are probably too critical to rely on a computer-based system for quick response.

A third point has to do with “nuisance” service requests. Some facility managers are concerned that making it easy to submit service requests will increase the number of service requests. One of the occupants who we interviewed said they would submit more service requests if it were easier to submit them. Although the service request rate was higher during the post-deployment period, it is not apparent from the results of the field trial that the user interface changes the rate at which service requests are submitted. The hypothesis test failed to produce a test statistic large enough to conclude that the differ-

ence is real. The fact that the requests come from just three users makes the results even less conclusive. More data are needed to conclusively determine the impact of the user interface on the frequency of service requests.

The user interface is appropriate for any size building. It could be useful for organizations with a single building, for a campus of buildings, or for organizations that have a set of buildings distributed over a large geographical area. It could be used to augment a maintenance call center, reducing the labor required for the call center.

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APPENDIX: INTERVIEW QUESTIONS

TENANT INFORMATION

How long have you been working in this building? _____ mos/yrs

How many service requests have you reported in total? (an approximate number) _____

How many service requests do you report on an AVERAGE

week? _____

month? _____

CALL-IN SERVICE REQUEST

How do you report Service Requests? (please circle)

Phone Call Other: _____

How satisfied are you with the current way to report service requests? (please circle)

1= Very Satisfied ... 5= Very Unsatisfied

1 ----- 2 ----- 3 ----- 4 ----- 5

Have you had any issues with the calling service? (please circle)

YES | NO

If yes, why (check all that apply):

- _____ Agent did not accurately enter data
- _____ Long wait to reach agent
- _____ Phone not always available when attempting to report issue
- _____ Other, please explain: _____

Would you make any changes to the call service? (please circle)

YES | NO

If yes, please describe: _____

Overall, how satisfied are you on the call service to report building service requests?
1= Very Satisfied ... 5= Very Unsatisfied

1 ----- 2 ----- 3 ----- 4 ----- 5

Would you use a web (internet) based form to submit service requests and check their status?

YES | NO

If yes, why? Easier to use
 No waiting time on the phone
 Other: _____

If no, why? Hard to use
 Not familiar with using a web browser
 Other: _____

Would you like to be contacted about the status of a service request that you have reported?

YES | NO

If yes, how? _____ Email
 _____ Phone Call
 _____ Pager
 Other: _____

Have you filled out more than one service request for the same issues?

YES | NO

If yes, why? _____ To have the issue addressed quicker
 _____ Didn't hear back on status of the service request
 Other: _____

On average, how long does it take for you to hear back on service requests that you have submitted?

- Less than 1 hour
 - Over 1 hour
 - Over 2 hours
 - Over 3 hours
 - Over 6 hours
 - Over 12 hours
 - More than 1 day
 - More than 3 days
 - More than 1 week
 - Never
 - Other: _____
-

If it would be easier to report service requests, do you think that you would report them more frequently?

YES | NO

- If yes, why?
- Ensure that the service requests are addressed quickly
 - There are a lot of problems that occur in the building
 - Other: _____
-

Please add any more comments here: _____

DISCUSSION

Jim Coogan, Principal Engineer, Siemens, Buffalo Grove, Ill.:

Your data suggest that the system reduced the number of complaints reported. Do you have enough information yet to support that conclusion?

Luis Villafana: No, we don't have enough information to

support the conclusion that the use of the tenant interface reduces complaints. The chart shown on the presentation outlines the usage pattern of three lead users. These three used the phone along with the tenant interface. But, one of these three lead users stopped using the application.