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KEY FACTORS FOR SMART HOUSE QUALITY ASSURANCE

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ABSTRACT

A smart house is one of up today technologies. Its quality is a very difficult question due to a variety of dimensions. This paper analyses current directions of smart house system technology improvement. Current studies are mainly dedicated to the integration of Internet of things (IoT) into smart house systems; specification of older people needs; specifications of sensors in smart house system; management and information management with the help of smart house systems; estimation via life quality changings.

Moreover, based on the Pareto chart and Shewhart control chart, the paper studies quality of the systems. The main purpose of the paper is to find out what is the main factor of quality assurance. The paper takes into account seven different parameters. According to the current study results, it is the users' classification.

Currently, the estimation of meeting users' expectations is very contradictory. In other words, some users are excited by the system, whereas the others are disappointed. Users studying should be specified in future studies due to in other aspects of quality improvement there no such opposite intentions. This study shows that users can estimate the smart house system quite differently. As a result, users' segmentation for the smart house is the main task for future studies. Providers of smart house systems have to take it into account either.

Disciplinary: Quality Management, Applied information Technology.

1. INTRODUCTION

The smart house technology is quite popular nowadays. This system includes two main types of smart houses: personal and community. The system of the personal smart house can be integrated by any person in their house. It usually covers:

- comfort, that assumes the realization of a specified program by the command;
- security, including video surveillance systems, alarm systems, access control, remote

access, fire safety systems, protection against water and gas leaks, etc.;

  - entertainment, including control of different multimedia devices, special programs for them, integration and restrictions;
  - climate control and heating systems that provide a healthy environment and life safety.

Thus, personal smart house systems are directed on quality of life increase. Whereas common smart house systems cover security, on the one hand, and processing, on the other. Security in these systems quite similar to personal ones, but includes more control options. It is determined by the object of control. For example, it is easier to reallocate resources in the house or even in the whole district, than in a separate flat due to control abilities. Processing for common smart house systems means process organization and optimization. It can include different aspects of control, such as gas and water, elevators, garbage disposal, etc.

Anyway, both smart house technologies include:

- system of sensors, detecting main parameters in the real-time mode;
- decision-making system, that covers:
  - possible decisions database;
  - explanation of what is the optimal solution, including its criterion;
  - algorithms of optimal solution selection;
  - algorithms of situation estimation that implies new data;
- regulation system;
- system of mechanic devices to realize regulation.

In this paper, the realization of personal smart house technology is analyzed with the help of quality assurance methods. The main purpose of the paper is to find out what is the main factor of quality assurance. As a result, the paper suggests some options for quality improvement.

2. LITERATURE REVIEW

Literature dedicated to smart house quality can be divided into several groups. The first group involves integrations of the Internet of things (IoT), with different systems and devices into one system (Parkhomenko et al, 2019). They suppose interactions inside the system and with the external world via the Internet. Undoubtedly, IoT is an important part of the smart house system quality, whereas the issue of this paper does not limit by IoT. The subsection of the first group is data processing for IoT. Scientists try to find the best way to collect and analyze data to improve smart house systems (Lee, et al, 2016). Moreover, Big Data technology (Nazarenko and Khronusova, 2017; Nazarenko et al, 2019) is important in these studies. This technology allows summarizing data, including unstructured one, for analysis and prediction of users' behavior (Tulenkov et al., 2019).

The second group dedicated to the specific needs of older people, concentrating on how older people can use this technology, what it can give them and which specifics it should have for this customer group (Stefanov et al., 2004). Moreover, this group of reteaches provides the specification of analysis for older people (Sanchez et al., 2017). The result of the studies is the set of factors that specify older people, which use smart house technology, and their needs (Nguyen, et al, 2019). This group the studies is very important for this research due to its assumption about different groups of smart houses customers (Lobanovsky, 2018).

The third group includes different specifications of sensors in a smart house system. Undoubtedly, both sensors (Jurenoks, 2017) and hardware (Vladimirovich, 2017) are important for quality assurance. However, these papers concentrate on information management plus the hardware of sensors. The fourth group of articles is also dedicated to management and information management with the help of smart house systems (Shutov, et al, 2020). However, it focuses on different aspects of measurable quality, such as quality of air, especially in the comparison between indoor and outdoor (Schieweck et al, 2018) and elevator timeout (Prusov et al., 2019). The main idea of quality estimation in these studies is the analysis of different components. The overall quality of the smart house is a combination or sum of its components' quality. Undoubtedly, overall quality depends on its components but does not come down to it.

The fifth group of studies attempts to estimate the quality via life quality changes (Corradini et al., 2017; Nazarenko et al., 2019) that can be measured but this estimation is not very accurate (Fitriaty et al., 2018; Nazarenko, 2019). These articles cover a very significant issue. The quality of a smart house cannot be reduced to the quality of its components. Moreover, it is not just the quality of living that raises with the help of this technology. It should also take into account other factors, including external influence. The main issue is how to measure all of these factors.

This study attempts to measure hardly measurable factors. The main purpose of the paper is to find out what the key factors of quality assurance are.

3. METHOD

3.1 OBSERVED VARIABLES

According to all mentioned above, it can be formulated a list of criteria and quality requirements for smart home system:

1) accuracy of key indicators, especially in safety, comfort and climate modules;
2) speed of decision-making;
3) speed of decision correction;
4) completeness of possible solutions and scenarios database;
5) effectiveness of adaptation to the situation;
6) user-friendly interface;
7) compliance with the user's expectations and perceptions of comfort, taking into account changing external conditions.

Based on this list, it should be noted that in addition to the analyzed criteria, it is important to determine the most relevant research methods. First, the Pareto diagram should be used to analyze the contribution of each of the seven factors to the overall performance of smart home systems. Thus, the most significant factors will be identified.

At the same time, each of the seven factors of the quality of smart home systems should also be analyzed in the context of the reasons that affect the quality violation. In the future, each of the seven quality factors is also analyzed using Shewhart control maps to determine the number of quality violations in a certain time, which means that the probability of a general violation of the quality of the system.

It is also important to note that the total number of Pareto charts should be eight, and the number of Shewhart control charts is seven. However, the results will be presented just significant ones, two Pareto charts, and seven Shewhart control charts.

3.2 SHEWHARTCONTROLCHART SPECIFICATION

Shewhart control maps can be implemented based on quantitative and qualitative criteria. They can be measured based on:

- individual value;
- sliding swings;
- average;
- standard deviation;
- medians;
- scope's;
- stability indicator (t-criterion).

Thus, the main criteria for the quality of smart home systems in the context of Shewhart control charts can be represented by the following indicators:

1. the accuracy of accounting for key indicators, especially in the modules of safety, comfort and climate- t-criterion, the boundaries are respectively the limits of the norm of this indicator for each separately observed system;

2.speed of the decision - making-milliseconds in each case for many observations;

3. speed of decision correction - milliseconds in each case for several observations;

4. completeness of the database of possible solutions and scenarios – the scope of variation for each system, and this indicator should reflect redundancy control;

5. effectiveness of adaptation to a changing situation – engineer's rating points for each observation;

6. user-friendly interface - user rating points for each observation;

7. compliance with the user's expectations and perceptions of comfort, taking into account changing external conditions - user rating points for each observation.

4. RESULT AND DISCUSSION

Previously, the list of criteria and quality requirements for the smart home system was provided. Not all of them are equally important and essential. Therefore, to build a Pareto chart, you need to rank them in order of decreasing contribution to the final quality of the system:

1. Accuracy of key indicators, especially in safety, comfort and climate modules;
2. Effectiveness of adaptation to a changing situation;
3. Completeness of the database of possible solutions and scenarios;
4. The speed of decision-making;
5. Speed of decision correction;
6. Meeting the user's expectations and perceptions of comfort, taking into account changing external conditions;
7. User-friendly interface.

Thus, the most significant contribution to the quality of smart home systems is the accuracy of accounting for key indicators. In second place is the effectiveness of adaptation to a changing situation. On the third – the completeness of the database of possible solutions. Together, these three quality criteria cover more than 70% of the overall quality of the smart home system, as shown in the Pareto chart (Figure 1). While the two final indicators related to consumer expectations and the interface contribute to quality only in the region of 8%. Of course, these aspects are more important for consumers, but this is more about the marketing component than the quality component.

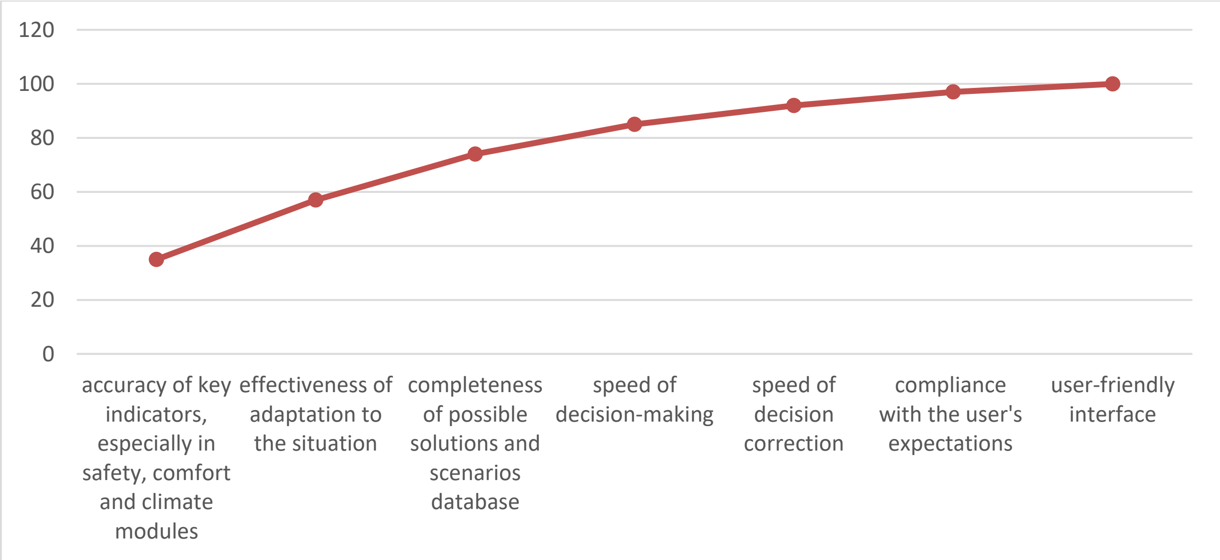

Figure 1: Pareto chart for smart house system quality

Thus, the first of the quality criteria, the accuracy of accounting for key indicators, especially in the modules of safety, comfort, and climate, consists of the variables mentioned earlier. At the same time, the greatest contribution to quality is made by the serviceability and proper functioning of each sensor (Figure 2) and is 35%. While the measurement error adds another 24% to the quality of the measurement accuracy criterion. Together with the information processing system, their overall contribution to the accuracy of measurements as a quality parameter is 76%. While errors of the first and second types, which close the list of requirements for the quality of measurements, make up only 13%. In other words, the first three criteria are as pronounced for this quality criterion as the first three criteria for the quality of the smart home as a whole. Figure 3 shows the Shewhart control chart for accurate tracking of key indicators, especially in the safety, comfort, and climate modules.

So, according to the presented data, the violation of the regulatory boundary occurs only from above. In other words, the data exceeds their variation significantly. This situation can be caused by two reasons:

- measurement error at the point;
- estimation error due to measurements.

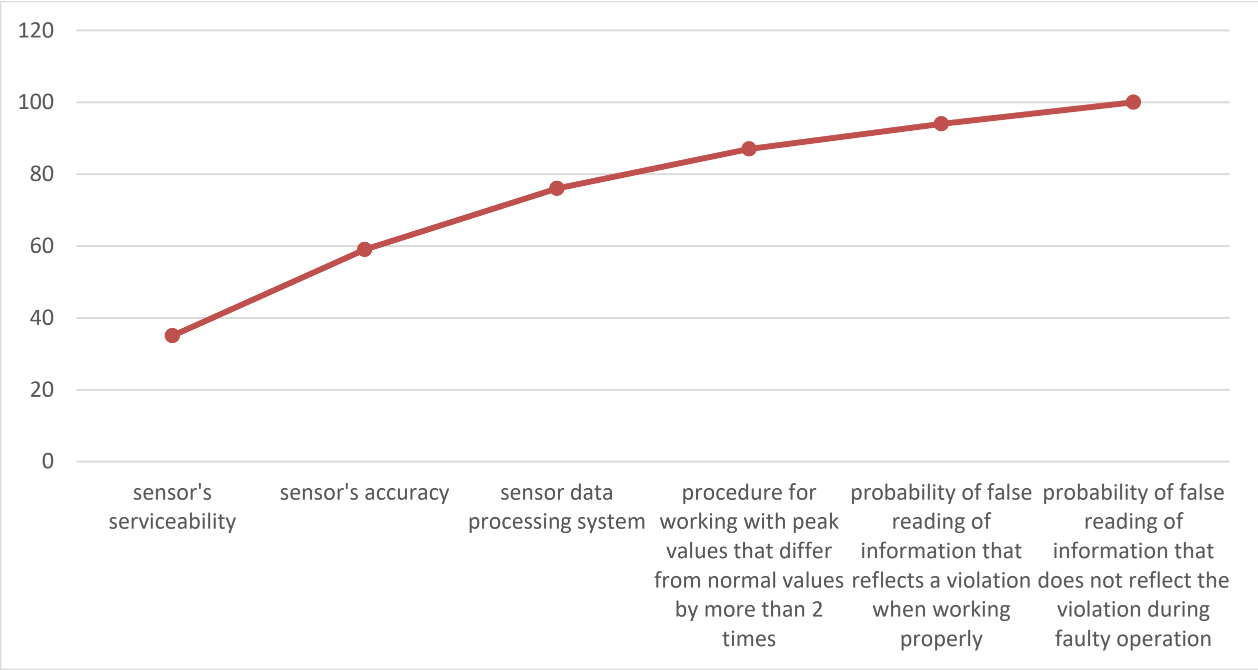

Figure 2: Pareto chart for accuracy of key indicators, especially in safety, comfort and climate modules

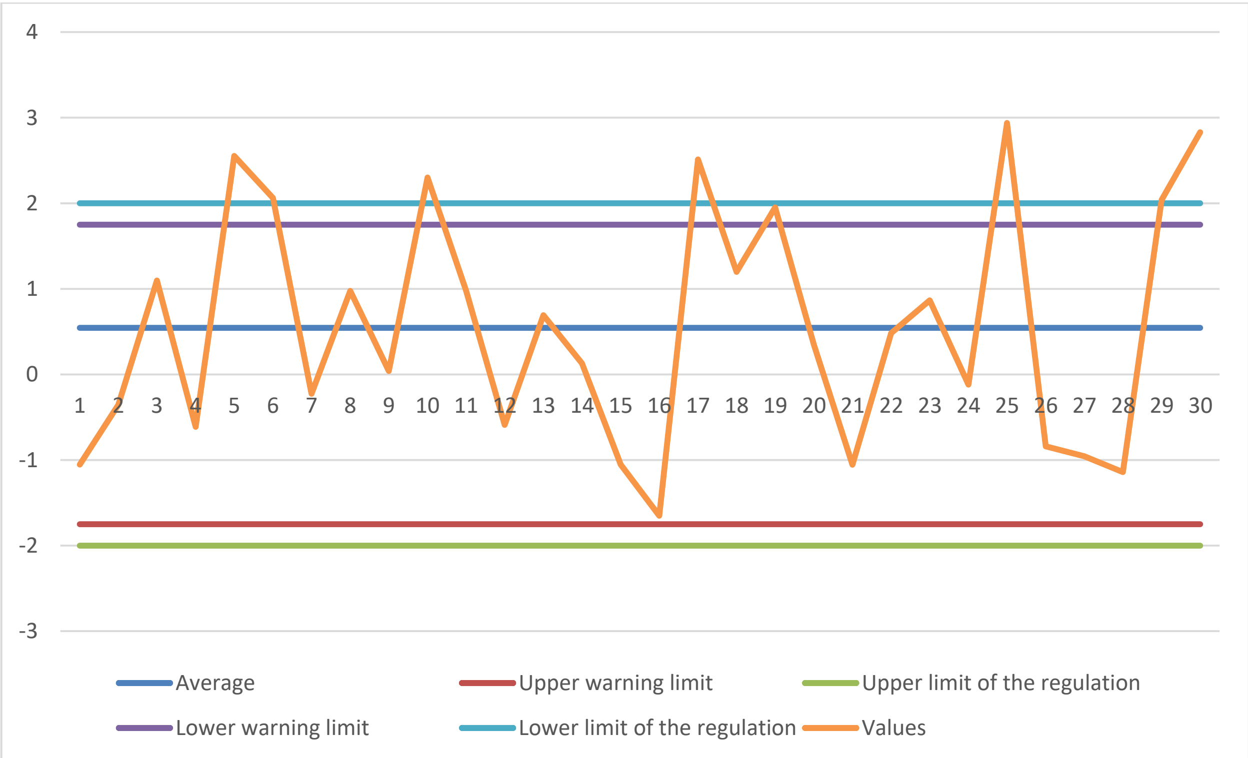

Figure 3: Shewhart Control map for accurate accounting of key indicators, especially in the modules of safety, comfort, and climate

We are talking about the fact that the system assumes peak values that significantly stand out from the normal ones. In some cases, this is due to external factors, such as water leaking from a tap. However, in most cases, it is the measurement error that leads to a false trigger of the algorithm. As a result, we can talk about excessive regulation and the need to improve the measurement and response of the system to indicators outside the norm. For a more accurate analysis, we will refer to the Shewhart control cards for other quality criteria.

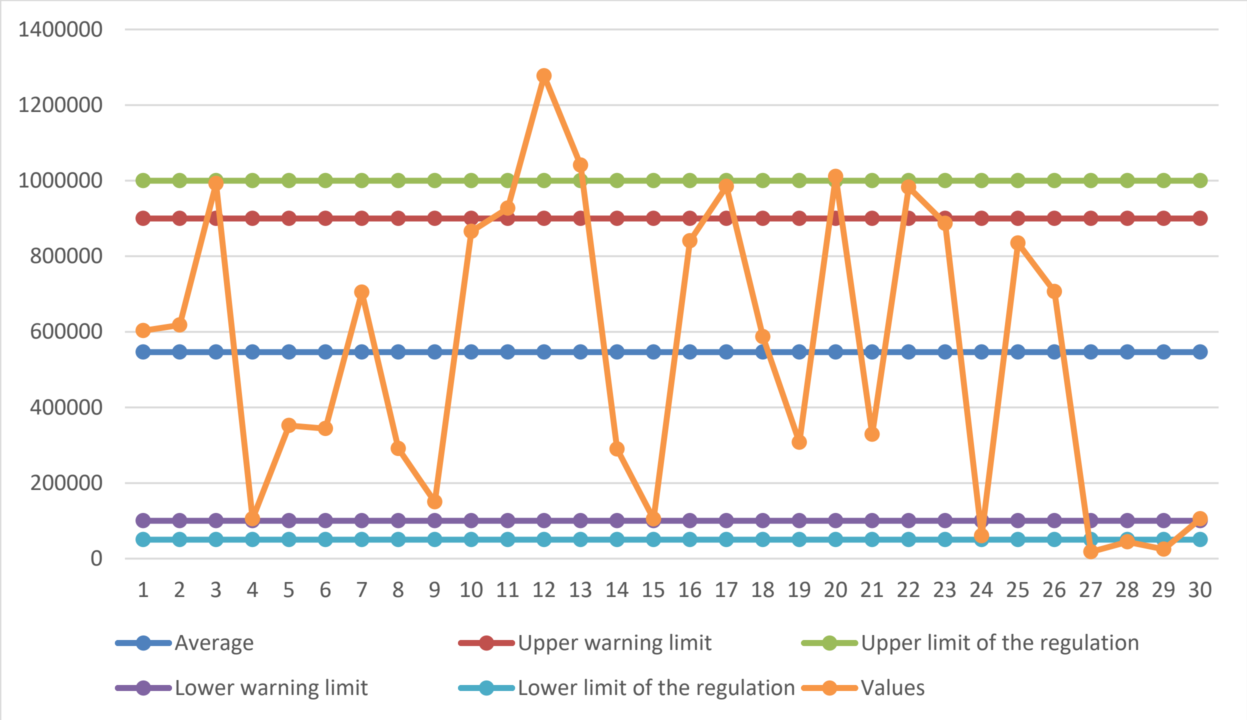

Figure 4: Shewhart control chart for decision-making speed

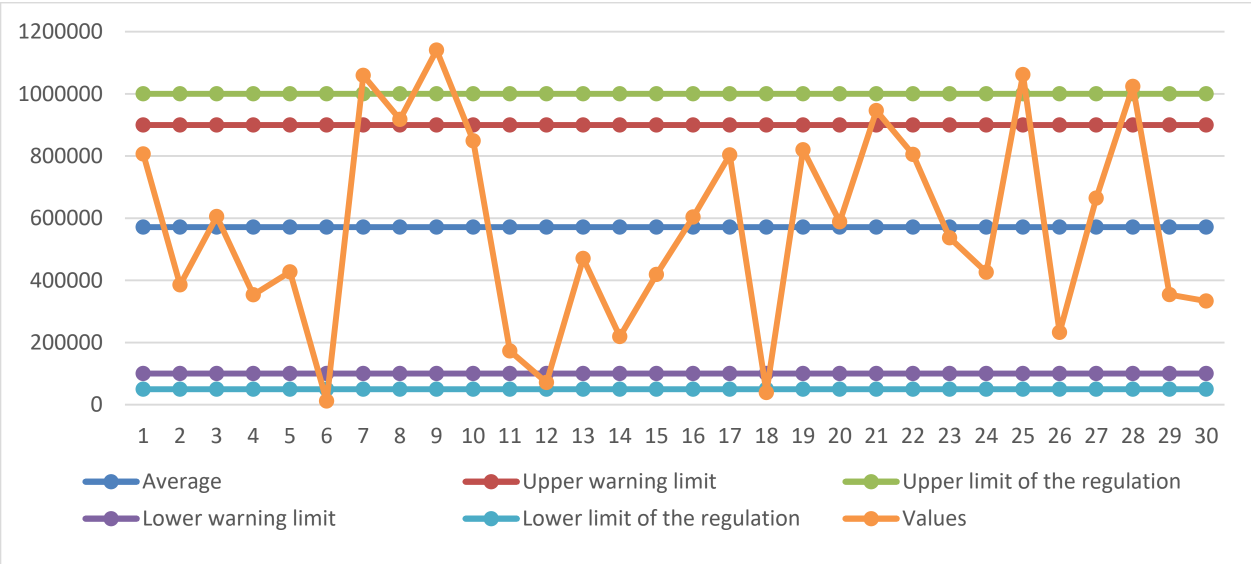

Figure 5: Shewhart control chart for the speed of decision correction

Figure 4 shows the Shewhart control chart for decision speed. So, the speed of decision-making is much more within the limits of regulation than the accuracy of accounting for key indicators. In particular, we are talking about the fact that there are three points on the upper border of regulation, and three more intersect it. At the same time, there are two points on the lower border, and two intersect it. Thus, the overall stability of the indicator is not very high, since 10 out of 30 observations reach one of the control borders. However, unlike the accuracy of observations, this boundary is reached both from above and from below. Although the overall upward bias is maintained. Thus, we can say that the speed of decision-making should be stabilized by reducing the excessively long response and average time. Attempts to reduce it by overreacting are not effective. Figure 5 shows the Shewhart control chart for the speed of decision correction.

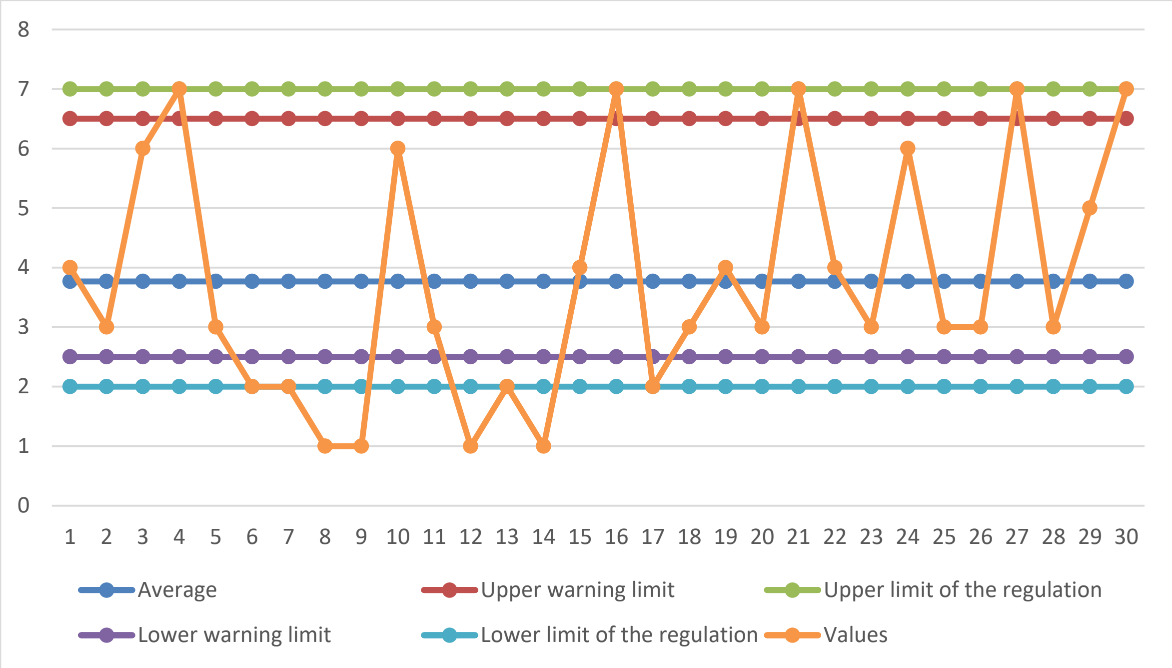

Figure 6: Shewhart control chart for completeness of the database of possible solutions and scenarios

In one observation, the rate of decision adjustment goes beyond the lower limit of regulation. At the same time, two observations lie on the lower border of regulation. In four observations, the upper limit of regulation was exceeded. Thus, in 7 observations there was a border crossing. Note that such dynamics are also excessive. However, the average value is close to the true average. In other words, in general, the speed of decision adjustment is within the statistical norm. However, it is also necessary to adjust the speed of decision adjustment in critical situations. At the same time, we are talking about exceptional situations. Note also that the speed of decision-making is less stable than the speed of decision correction. Figure 6 shows the Shewhart control chart for completeness of the database of possible solutions and scenarios.

The upper limit of regulation was never violated when observing the completeness of the database of possible solutions. At the same time, 5 observations lie on the border of regulation. While 4 observations lie beyond the lower limit of regulation, and another 3 – on it. As a result, it can be argued that in 12 out of 30 observations, there is a violation of the quality boundary. Thus, the process is extremely unstable. At the same time, the average content of the database of possible solutions and scenarios is lower than the real average. We are talking about the fact that the base as a whole is not filled enough, which leads to excessive deviations along the lower border. As a result, we can say that it is necessary to fill the database in General, and not exclude individual incidents.

Figure 7 shows the Shewhart control chart for effective adaptation to a changing situation.

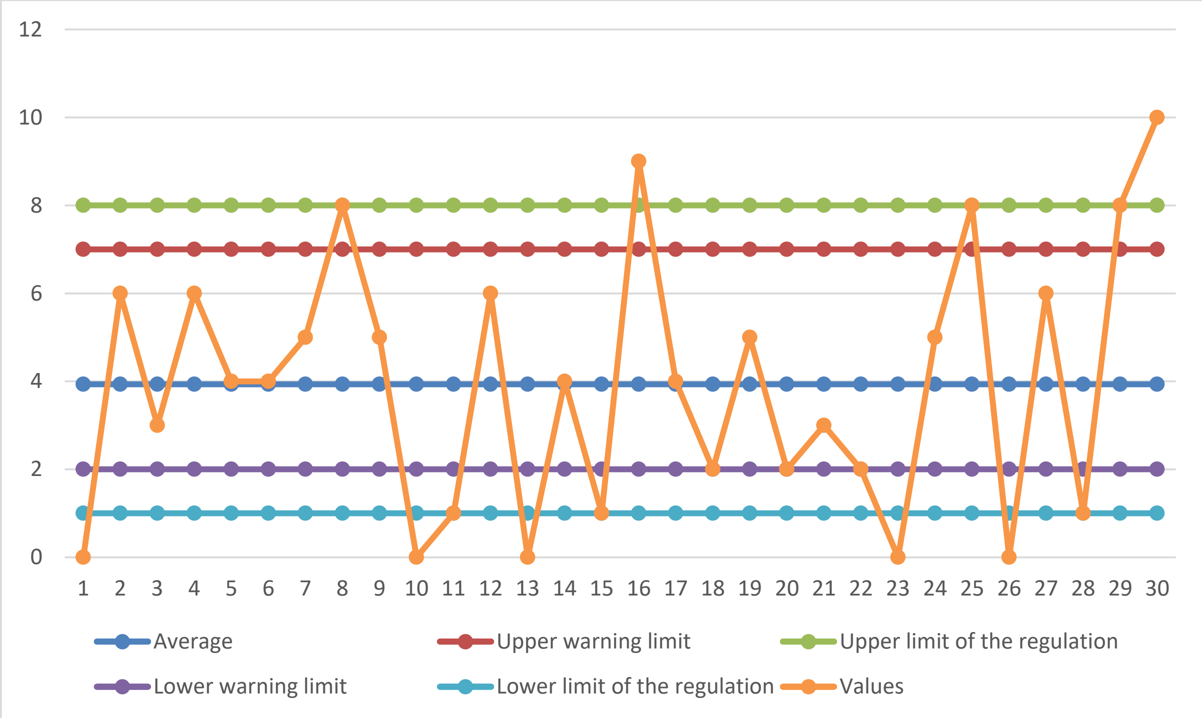

Figure 7: Shewhart control chart for effective adaptation to a changing situation

The process of effective adaptation to a changing situation is not stable. At the same time, in 5 cases it goes beyond the lower limit of regulation and is extremely inefficient. In two cases, the lower limit of regulation has been reached. While in one case-the the upper limit of regulation is exceeded and it is excessive. Simultaneously, the upper limit of regulation was reached in five cases. In other words, in 13 cases, the regulatory boundary has been reached or crossed. However, the regulation itself is not biased relative to the average. This means that regulation is either insufficient or excessive. It is important to note that the situation itself is relatively stable and requires both removing excessive regulation in some situations and adding it in others.

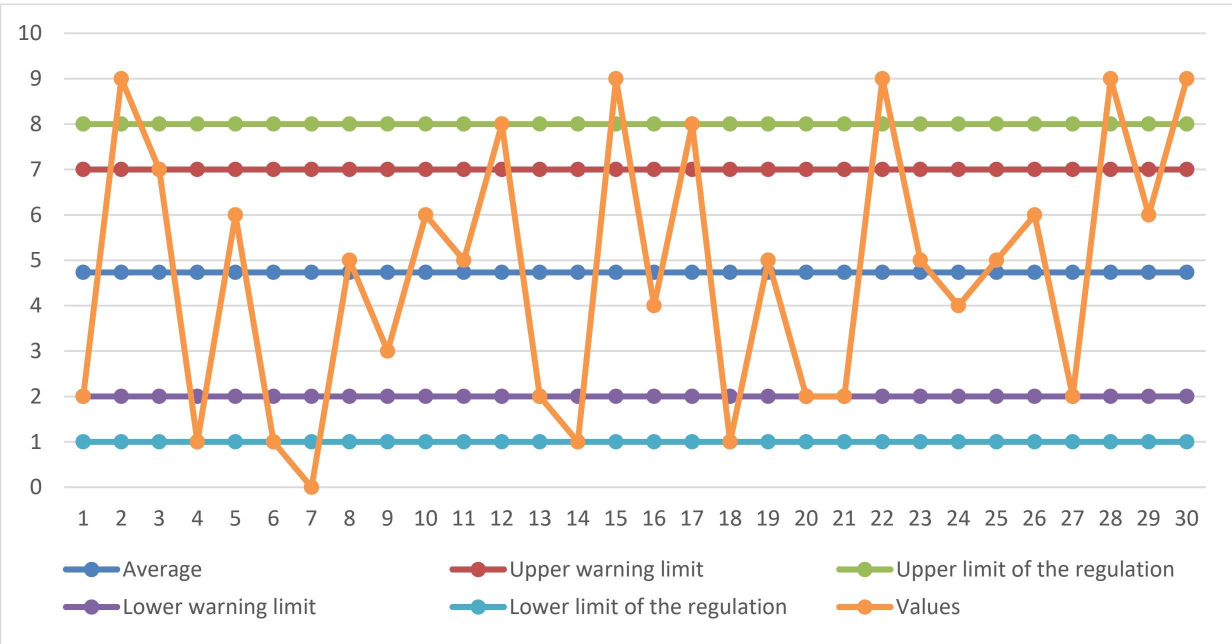

Figure 8:Shewhart control chart for accessibility to the user interface.

The overall accessibility of the user interface is skewed towards the upper limit. At the same time, in three cases there was a violation of the upper limit of regulation, and in 3 cases it was reached. The violation also affected 3 observations at the lower limit of regulation and three beyond it. Thus, it can be argued that the process is slightly shifted to the positive zone, while the overall dynamics are extremely unstable. It requires a large adaptation to the real expectations of users, perhaps their segmentation, instead of the same type of solution.

Figure 9 shows the Shewhart control chart to match the user's expectations and perceptions of comfort, taking into account changing external conditions.

Based on the data presented in figure 9, it becomes obvious that the process is extremely unstable and this quality indicator requires serious adjustment. In particular, in 30 observations, 5 cases of violation of the upper border, 2 more of its achievements, 4 cases of crossing the lower border, and 4 of its achievements were recorded. Thus, the number of points where the system has demonstrated its inefficiency has reached 15, which is 50%. Note that in general, the average is shifted up. Thus, it can be argued that less regulation, General smoothing of the process, and segmentation of user groups are required.

Based on all of the above and analyzed, the most critical aspects of the violation of the quality of smart home systems are:

- inaccuracy of sensor processing;
- redundancy of regulation;
- incompleteness of the rule base;
- mismatch between the expectations of users;
- insufficient response time;
- the acceptable time of the overshoot.

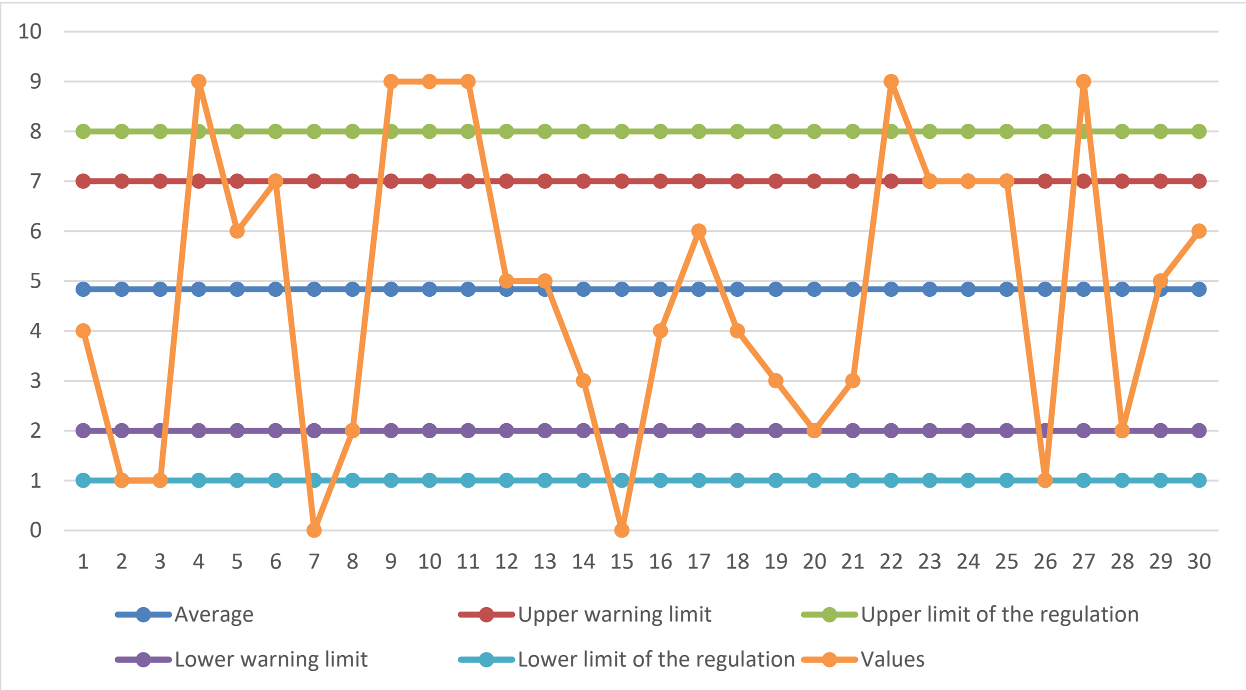

Figure 9:Shewhart control chart for user's expectations

5. CONCLUSION

The paper shows that studies in the fields of databases for the smart house and dedicated to IoT are very important for the quality of the system assurance. However, the most significant issue is users' classification or dividing into different groups. The issue is not only found in older users. Currently, their estimation of meeting expectations is very contradictory. In other words, some users are excited by the system, whereas the others are disappointed. Users studying should be specified in future studies due to in other aspects of quality improvement there no such opposite intentions. This study shows that users can estimate the smart house system quite differently. As a result, users' segmentation for the smart house is the main task for future studies.

6. DATA AND MATERIAL AVAILABILITY

Data can be made available by contacting the corresponding author.

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