

PAPER

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The level of generalized technology readiness of the Smart House automation systems

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Abstract. The article assesses the Technology Readiness Level (TRL) according to the developed TRL checklist. The TRL approach has been applied to analyzing the technology readiness level of a Russian start-up company producing systems of multisensory and multifunction devices for Smart House. The authors approbated the modified TRL methodology, which made it possible to evaluate the readiness of technologies' integration among themselves and to get a generalized assessment of the readiness of the technologies' system – Integration Readiness Levels (IRL). It has been proved that the System Readiness Level (SRL) of technology corresponds to the design concept stage. Taking into account indicators and means of quality assurance at the stages of design and initiation of such production is highly relevant.

1. Introduction

For implementing projects in innovative enterprises, planning the quality management process of the technology under development is of great importance. There are generally accepted quality management planning tools [1, 2], a list of which is described in detail in current Russian and international standards (see for example [3]). The section “Quality Management” in the body of knowledge of the Project Management Institute (PMI) is based on the quality standards of the International Organization for Standardization (ISO).

In this article the researchers propose new methods of standardization and implementation of norms and requirements in organizations [4]. It should be noted that all the presented tools are pertinent to operating enterprises. When developing completely new technologies or introducing innovative techniques, such solutions may not always be used because of the incapability (of certain categories of such products) of identifying the requirements and quality standards. It is necessary to state that the consideration of indicators and means of quality assurance at the stages of initiation and design of such production is extremely significant [8].

There are no quantitative methods to evaluate the readiness of the technology and the possibility of its scaling for entering the market, to give an objective assessment of the Technology Readiness Level (hereinafter referred to as TRL) concept, and as a result, to determine adequately the necessary resources before the project has been completed. Now, for determining the level of readiness of scientific and technical projects enterprises use an algorithm, which is based only on expert assessments [5]. At the same time, there is a lack of standardized algorithm for conducting such a qualitative analysis; each company develops and applies its own expert systems and systems of indicators, which incorporate



various assessment methods. This hinders the work on inter-organizational and inter-sectoral monitoring of the portfolio of innovative projects of companies and identifying the most promising ones.

One of the progressive methods used by specialists in different countries to solve the problem is the assessment of the Technology Readiness Levels (TRL) according to the developed TRL checklist. Originally, this method was used by experts to assess the readiness (maturity) of the technical systems being developed for the aircraft industry [6], but now these quantitative metrics are used in other areas, so they can be considered unified so far [7].

At any given moment in time TRL is a tool for assessing the technology readiness, which enables the technology classifying by comparing typical works having been performed, the conditions for doing these works, as well as the required documentation support for one level out of nine [9].

When creating a system from a set of technologies, it is critical to address the issue of compatibility of the technologies being developed between themselves as early as at the development stage. This is to be done to assess the level of readiness of the integrated technologies in a single system. The modified TRL algorithm, called Integration Readiness Levels (IRL), is a checklist for assessing the level of systems' readiness in their mutual integration. It is not unlikely that even in the case of a high level of maturity of individual components, the system may not be complete, if the procedures for the interaction of its subsystems have not been defined [10].

The use of this tool helps not only to control the process of the development life cycle, but also to analyze the portfolio of projects to make informed management decisions. When assessing the readiness of subsystems and their integration, some of the parameters to be evaluated are the quality indicators of the products or technologies being developed, so that one can determine in advance the essential constituents of the process from the point of view of quality, take these constituents into account when designing business processes and ensure that the results meet the specific requirements of the investor, consumer and the very production process.

2. Materials and methods

In this study, the application of the TRL method is demonstrated on the example of a Russian innovative start-up company implementing a project of a system of multisensory automated control of devices inside a house.

The evaluation and analysis of the system of related technologies was performed in the following order:

1. We took that the technological system is a set of independent subsystems with internal possible connections and the specific procedure of interaction of the subsystems with each other.

2. According to the developed (TRL) checklist, the values of the technology readiness level for each subsystem were calculated.

3. In accordance with the developed modified check list (IRL) and taking into account the identified interactions within the integrated system, we assessed the readiness of the technology components' integration with each other.

4. We then performed a quantitative assessment of the maturity of the system as a whole.

The application of the above described technique was made on the example of a project for developing a multisensory and multifunctional automated control system for devices inside a house.

The aim of the multisensory and multifunctional system for devices in the smart house is to integrate a number of automation elements while minimizing the settings used by the consumer (Figure 1). In contrast to the existing approaches to automating the control of individual devices, this solution integrates all sensors both at the physical level (integration in one package) and at the software level (one and only one application for settings and control).

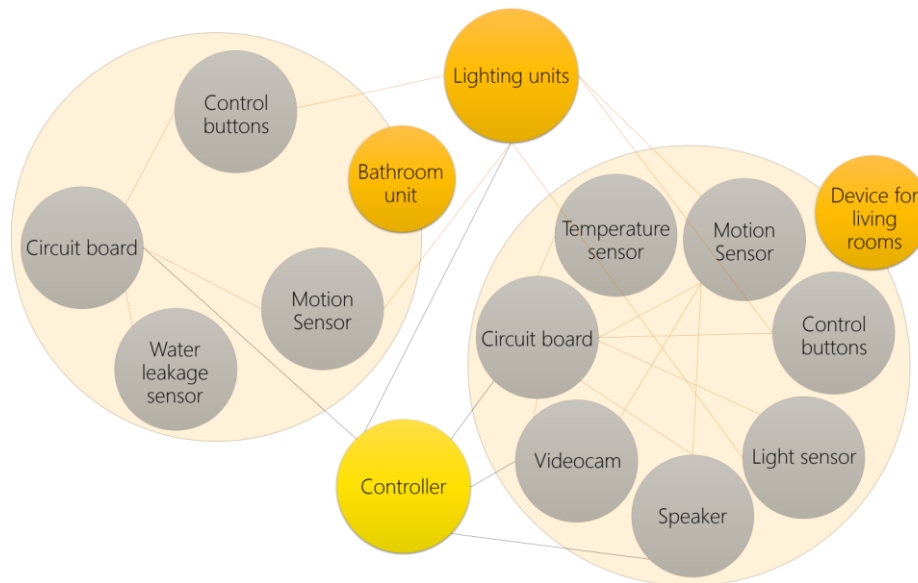


Figure 1. System of automation elements.

The system includes:

- 1) Controller (control system);
- 2) Controllable devices for residential space;
- 3) Controllable devices for rooms with high humidity (bathroom, kitchen);
- 4) Controllable lighting units.

Separate devices of the dwelling unit will have sensors controlling the dynamics of the music system, light and temperature, as well as managing the security system, including a video surveillance camera and motion sensors. In the device for the bathroom and kitchen, the necessary units are those of control, temperature sensors, motion sensors and water leakage sensors. The entire range of sensors is managed by the controller.

The most common automation standard – Z-Wave (frequency range up to 1 GHz) will be used to transfer data between devices. The controller will be based on the RaspberryPi single-board computer and the RaZberry extension to support the Z-Wave protocol, while the Z-Uno boards will be applied in the devices for the living rooms and the bathroom.

We are able to distinguish the following estimated quality parameters of the system: the number of false alarms of the sensors, the number of events unrecorded by the sensors, errors during the program's work, work time of devices without recharging.

Assessment of the level of readiness of technological solution subsystems

To assess the TRL, a team of four experts was called together, and the final score was produced as an average of expert ratings.

1. The controller. For the 6 years of the existence of the RaspberryPiN single-board computer device, many automation solutions based on it have been created, and the sales of this computer have exceeded 12.5 million units [6]. In this study, it is obligatory to introduce a ready-made technology into a real device, therefore, the requirements correspond to the level 7 of readiness, whereas the maturity coefficient is estimated to be 0.67 points;
2. Devices for residential space. The key elements of the devices (sensors, camera, speaker and controls) were identified and partially characterized, the means of conducting video surveillance and music playback will have to be worked out, therefore, this constituent corresponds to level 3 of readiness, whereas the technology maturity ratio is 0.23 points;
3. Device for rooms with high humidity. There are no studies showing that the components of the system can function together, therefore the readiness level is rated as 3, the maturity coefficient is 0.23 points;

4. Controllable lighting elements. A large number of manufacturers offer lighting elements controlled by a smartphone, such solutions have been sold on the market for several years. The most popular manufacturers are Philips, Xiaomi, LIFX, Rubetek and others. The level of technology readiness is 9, whereas the maturity coefficient is 0.98.

Evaluation of the level of subsystems' integration

1. Controller and systems for residential space. The specificity and carrier of the integration of individual system technologies were defined. RaZberry extension is to be used to support the Z-Wave data transfer protocol. The possibility of recording and broadcasting from a video surveillance camera is to be investigated. The level of technology integration is 2, the integration readiness factor is 0.2;
2. Controller and devices in bathrooms. The data from motion sensors and water leaks sensors in the bathroom will be transmitted to the controller to send alerts to users. These two technologies can successfully exchange information and communicate in a useful way, therefore, the technology integration level is 4, the integration readiness factor is 0.34;
3. Controller and lighting systems. When a motion sensor is triggered, the signal from the controller is transmitted to the lighting units for their automatic switching. The components of the system are reliably controlled and can form a single system, thus, the technology integration level is 5, the integration readiness factor is 0.5;
4. Devices for living rooms and a unit for the bathroom. Due to the peculiarities of the data transfer standard, devices for rooms can transmit information to the bathroom unit from the controller. Technologies can successfully exchange information, so the level of technology integration is 2, the integration readiness factor is 0.15;
5. Devices for living rooms and lighting units. As in item 3, when a motion sensor is triggered, a signal is transmitted to the bulb to turn on the light. At this point, the motion sensor is built into the device based on the Z-Uno board, the individual parameters will be configured via the application and the controller, therefore the technology integration level is lower than 4, the integration readiness factor is 0.35;
6. Devices for bathrooms and lighting units. The characteristic is similar to item 5, the level of technology integration is 4, the integration readiness factor is 0.35;

As a result, the final technology readiness matrix takes the following form:

$$TRL = \begin{bmatrix} 0.67 \\ 0.23 \\ 0.23 \\ 0.98 \end{bmatrix}$$

The final readiness of technology integration is presented in table 1.

Table 1. Subsystems' Integration Readiness Levels.

	Controller	Devices for living rooms	Bathroom unit	Bulbs
Controller	1	0.2	0.34	0.5
Devices for living rooms	0.2	1	0.15	0.35
Bathroom unit	0.34	0.15	1	0.35
Lighting units	0.5	0.35	0.35	1

The integration readiness matrix is as follows:

$$IRL = \begin{bmatrix} 1 & 0.2 & 0.34 & 0.5 \\ 0.2 & 1 & 0.15 & 0.35 \\ 0.34 & 0.15 & 1 & 0.35 \\ 0.5 & 0.35 & 0.35 & 1 \end{bmatrix}$$

$$[SRL] = [IRL] * [TRL] = \begin{bmatrix} 1.2842 \\ 0.7415 \\ 0.8353 \\ 1.476 \end{bmatrix}$$

$$SRL = 0.271$$

3. Discussion

Interpretation of the SRL indicator, which is the maturity index of the technical system being developed, will be carried out in accordance with table 2.

Table 2. Interpretation of Maturity Levels values.

SRL	Phase
0.90-1.00	Maintenance and support
0.80-0.89	Production
0.60-0.79	Development and demonstration of the system
0.40-0.59	Technology development
0.10-0.39	Concept

As can be seen from the table, the level of the technology maturity corresponds to the stage of the project concept. The main tasks facing the project developers at this stage are the improvement of the initial concept and the development of a further system strategy.

Hence, the joint use of TRL and IRL shows an opportunity of introduction not only in the practical project management in the field of aviation, but also in high-tech project management in other industries. The above considered tools can be used at such stages of project implementation as “Planning and Implementation” and “Monitoring and Control” together with the basic approaches enshrined in the PMBOK. At the “Planning and Implementation” stage of the project, TRL and IRL can be used for making a work plan, including its decomposition into work packages and project milestones to create a system for assessing the degree of product development and coordination of expected results and deadlines between stakeholders. At the “Monitoring and Control” stage, these tools can be used to assess the quality and extent of project implementation in terms of the readiness of the product to enter the market, including its integration into the relevant field of activity.

4. Conclusion

This technique is new and requires relatively high knowledge regarding the world level of development of the technologies being produced and integrated; as a consequence, its application is not so extensive, especially in analysis of Russian start-up companies. However, this assessment system can become a source of useful information for project planning, as well as a tool for monitoring the progress of project realization at various stages of its life cycle. Such technical expertise can be effectively used by project portfolio managers to assess the state of the system or the program, which will give the chance to those responsible to react quickly, identify and add to the portfolio the necessary technology projects for successful integration and, if necessary, to reorient their activity.

Involving quality management parameters in the process of assessing the technology readiness for a product under development brings an opportunity to pre-evaluate possible risks. In the absence of any parameters and methods for assessing the quality of innovation, the readiness factor will be lower, besides, developers will have to conduct research and design possible solutions for the transition to the next stage, which will lead to a clarification of the current situation.

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