University of Pardubice
Faculty of Transport Engineering

MOBILE APPLICATIONS FOR OPERATIONAL CONTROL OF RAILWAY TRANSPORT

DISSERTATION THESIS

2025

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Study program

P3710 Engineering and technology in transport and communications

Study specialization

3708V024 Technology and management in transport and telecommunications

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Content

Introduction

Mobile application development in the rail industry uses different approaches and technologies, which can lead to inconsistencies and reduced efficiency. This thesis focuses on unifying the mobile application development process to enable faster development, reduced costs and improved user efficiency. The focus of the dissertation is on internal railway applications, which are mainly used to support the operational management of rail traffic.

The first phase of the research is an overview of the current state of the art, including an analysis of existing applications, technology trends and development approaches. It also includes an assessment of current development practices in the company, where the methodology is validated on a real project. Based on the system analysis, a system model is created as the basis for the solution design. The main needs and priorities of the mobile application development are identified, based on which five variants of the project focus are defined.

In the design part, based on the research results, optimisation measures are proposed to increase the efficiency of the development. The suitability of these measures for each system variant is determined using a multi-criteria decision-making method. The implemented measures are then analysed in terms of their impact on development efficiency and achievement of project priorities. An analysis of the combination of options is also carried out, not only to increase development efficiency but also to identify additional benefits beyond the original project priorities. In order to validate the methodology, a sample mobile application is designed according to the methodology, applying optimisation measures in all subsystems. A requirement gathering and analysis is performed, the application is defined and vulnerabilities are identified using a risk matrix.

This is followed by the technical design, including the selection of appropriate technologies, optimised user interface and data security. A sample part of the task is created for the programmer and a testing process is designed using automated tools. Documentation is structured to cover the main parts of the application and its integration with existing systems.

A comparison of development with and without the methodology allows an objective assessment of its benefits and effectiveness. Finally, the scientific and practical contributions of the work are evaluated.

1 Current state of the studied issue

For the efficiency and usability of mobile applications, it is essential to focus on the following areas during the application development process: user experience (especially the user interface and the ability to use the data network connection), the technologies used for development, security, the quality of the actual implementation, the quality of testing, life cycle management (installation, updates, distribution to users). In addition, the target application group has specific requirements for mobile devices, including GNSS receivers, and for data and communication standards that should be met. The key parameters were defined by the author in her previous research in Šmídová et al. (2023).

A review of the current state of the art shows that for all identified key parameters for mobile application development in the study area, both open source, free and commercial paid alternatives are available. Open source tools offer flexibility and low cost, but require more expertise and management. Commercial technologies offer professional support, automation and integration, but at a higher cost. The selection of specific technologies should be based on the priorities of the project.

An agile approach to software development, as described by Mock et al. (2021), based on an iterative process and adaptive planning, supports continuous adaptation to requirements and rapid delivery of quality products. Unlike linear methods with a fixed structure, it places greater emphasis on collaboration and continuous improvement. The analysis confirmed its suitability for the proposed mobile application development methodology in the study area.

The analysis made by Almadhoun et al. (2019) and Kasalová (2023) showed that the effective use of human resources is critical to the success of software projects as it has a direct impact on productivity, cost and quality. Smaller, well-coordinated teams (3-9 members) show higher efficiency due to easier communication and lower coordination costs, which is ideal for agile approaches. However, for projects with higher technical requirements, it is advisable to expand the team to include specialists. The optimal team composition and structure should match the specific needs of the project.

The company's mobile application development is flexible and adapts to customer needs and company capabilities, but there is room for improvement. The introduction of systematic and standardised practices could significantly increase efficiency and add value for customers and the company. Based on the analysis of the development process, a system model was created using the SSM methodology, which will be further optimised in the dissertation. The proposed optimisation measures depend on the priority of the specific project. In the addressed group of applications, the priorities in the project can be the lowest cost, the fastest development, the highest quality, the highest security or flexibility and scalability.

The quality of the resulting application can be significantly improved by targeting it to the specific technology platform on which it will run. In the group of applications under consideration, this approach is quite common as applications tend to run on single service devices.

The development of mobile applications in the addressed area is conditioned by legal regulations, technical norms and technology standards that ensure security, legal compliance, compatibility and efficiency. The Cybersecurity Act, GDPR, ISO standards and technology standards such as OWASP MASVS are key. These frameworks support quality security, data communication, user interface design and optimise the development process.

The literature analysed deals with subtopics in isolation - technologies for mobile application development, assessment of application users' needs, uniform format of train documentation in the EU, project management in development, etc. None of the works found deals with the combination of these topics, i.e. determining the specific needs of mobile transport applications for the internal needs of the railway operator for operational management and finding the most appropriate implementation procedure that could be further uniformly applied.

2 The aim of the dissertation

The aim of the dissertation is to **unify the process of designing mobile applications for railway operators** This is achieved by proposing a methodology that eliminates the need to repeatedly compare methods and technologies each time an application is developed or modified. To ensure maximum efficiency, the methodology focuses on mobile applications for operational control of railway transport.

The methodology serves the development teams of analysts and developers and is intended to ensure faster and more efficient development. In addition to saving time and costs in finding the optimal solution, it is expected to increase user comfort and efficiency, leading to increased productivity.

In order to achieve the main objective, the following sub-objectives have been defined:

- determination of key parameters for mobile application development,
- determination of specific requirements for mobile applications in the addressed area,
- summary of technologies that can be applied for a specific parameter with respect to the identified requirements, selecting among them using the specified scientific methods,
- design and validation of the methodology in a reference company engaged in the development of IS including mobile applications for leading czech carriers.

3 Processing methods and method of solution

The research uses a combination of empirical, logical and systematic methods that have been applied in each phase of the work. The empirical methods are used to analyse the current state of mobile application design and development in the reference company and to validate the proposed methodology. Logical methods are used to process the information obtained and then applied to design the solution and define the key points of the methodology.

Due to the complex nature of the problem, the systems analysis methodology described by Dudorkin (1995) is used. It is used to identify the system of the current state of mobile application development and to synthesise priority system options. To describe the system, a behaviourist definition is chosen, which characterises the system based on its behaviour and interactions in the environment. The system is developed using the Soft Systems Methodology (SSM), suitable for the analysis of human activity systems associated with technical elements; specifically, the Checkland Methodology as described by Checkland (1999), relevant to the intent of this thesis, is used

The Weighted Sum Approach (WSA), a multi-criteria decision-making method, summarized by Taherdoost (2023), was used to determine the

suitability of optimisation measures in each system variant. This method is used to quantify the evaluation of individual measures and their contribution to the optimisation of mobile application development. The semi-structured interview method explained by Hendl (2023) is used to optimise the collection of user requirements for the application, and the risk analysis method is used to identify the weaknesses in a particular project and propose measures to eliminate them.

4 Achieved results

4.1 Development of methodology

In the design part, the author has reflected the specific characteristics and needs of mobile applications in the addressed area in the identified key parameters for their design and development and supplemented them with requirements resulting from the legal and technical normative framework, thus defining the main areas on which she focused when designing the methodology.

At the beginning of the methodology, the author proposed an optimisation of the process of identifying the customer's requirements and needs for the application. She presented a quick and effective method of semi-structured interviews and prepared a specific guide focused on the specific needs in the area addressed. This approach makes it possible to obtain both obvious and hidden customer requirements, which then serve as a basis for the analysis of application requirements.

The next point of the methodology is the identification of risks in the application development process in a specific project. The author has proposed the creation of a risk matrix that allows to clearly and systematically identify key risks, assess their probability and impact on the project, and propose preventive measures.

Based on the analysis of the current state of the art and the identified specific needs of applications in the area under study, the author proposed a set of optimisation measures for the application development process. These measures target different aspects of optimisation, such as speeding up development, reducing costs or improving quality.

Based on the identified priorities of the projects in the subject area, the author has created five variants of the development process system with the help of SSM. These variants focus on lowest cost, fastest development, highest quality, highest application security, and flexibility and scalability - both of the application itself and of the development process.

Using a multi-criteria decision-making method, the author determined the suitability of each optimisation measure for the prioritised system variants. The measures found to be effective were implemented in the respective variants and their impact on the development process and the achievement of the priorities set was then analysed. It also considered the possibility of combining the variants to increase the efficiency of the process and the final product. It was found that some of the options could be successfully combined, while some combinations were not feasible. In these cases, the author suggested approaches to work with the customer to find alternative solutions to the project - e.g. adjustments to quality requirements, delivery date, budget or application functionality.

The author suggested the possibility of recommending a suitable mobile device if the application will primarily run on a single device type. This recommendation is based on the identified key device parameters for effective operation of the application in the study area. Thus, during the development process, it is possible to optimise the application for the specific technical parameters of the selected device.

The solution is based on the specific requirements of mobile applications in the solution area and systematically covers the key areas of development

with regard to legal and technical requirements. Through this targeted optimisation of individual steps, the methodology provides a comprehensive approach to increasing the efficiency and added value of the resulting applications and the development process itself.

4.2 Verification of the methodology

The methodology was verified in the real process of designing a mobile application in the reference company ČD-IS. It was verified on the design of a part of the real application - the mobile extension of IS PRIS, specifically the functionality "Editing a car - data from the PDV". The design followed the structured steps of the methodology. After determining the priority focus of the project, the appropriate system variant was selected and the relevant optimisation measures were applied. The first step was to identify the optimal team and technology for that variant. The elicitation and analysis phase effectively identified customer needs, which formed the basis of the application requirements and the design part. The next phase was the actual design of the application, which included technical design, user interface design, security, programmer task specification, test scenarios, documentation structure and deployment process description. For the development and testing phases, the effects of the implemented optimisation measures were analysed. On the basis of this experience, several retrospective adjustments and additions to the methodology were made, e.g. the timing of the introduction of optimisation measures and the addition of templates for standardised outputs.

The speed, quality and efficiency of application design using the methodology was compared with the original process carried out without it. The results showed that the methodology led to significant improvements in the organisation and management of the design, including faster identification of requirements, more effective communication between team members and higher quality outputs. In particular, the ability to adapt to the specific needs

of mobile applications in the transport sector, the streamlining of requirements gathering and the acceleration of the overall development process were appreciated. The standardisation of outputs greatly facilitated team collaboration and the long-term sustainability of the software. Some elements of the methodology have already been successfully implemented in real projects, where they have proven their benefits in terms of development efficiency and quality of outputs. It was recommended that it should be introduced in phases to facilitate team adaptation, and that simplified templates should be used for smaller projects. Overall, the methodology was evaluated as a practical and well-used tool that brings real improvements to development and has the potential for wider use in other areas of software development.

5 Benefits of the dissertation

The author considers the main contribution of the thesis to be a system view of mobile application development as an integrated whole, covering all phases from requirements gathering to deployment and further development. On this basis, a comprehensive methodology has been proposed that streamlines the entire process, including collaboration with the customer, and is adapted to the specific needs of railway applications.

An important element of the contribution is the validation of the methodology on the design of a real application, which allowed its refinement and adaptation to practical use. Already during the thesis, some parts of the methodology were implemented in a real development process, where they had a positive impact on the speed, quality and efficiency of the development.

The methodology also supports the long-term sustainability of software development through standardised procedures, templates and clearly defined processes. These aspects not only make development more efficient, but also make it easier to extend and maintain applications in the future.

Another important benefit is that the way in which the methodology has been developed allows it to be applied to other specialist areas. Although it was primarily designed for the internal mobile applications of railway companies, its principles can be adapted to other types of software projects thanks to clearly defined key requirements. This opens up possibilities for wider use.

During the research it also became clear that the proposed solutions could be further refined by using more sophisticated decision-making methods. The application of advanced MCDM methods in software engineering could improve decision making processes in technology selection, requirements prioritisation, optimisation of development, testing and management of software projects. This direction could be the next step in research with significant potential for practical applications.

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Souhrn/Abstract

Tato disertační práce se zabývá návrhem systematické metodiky pro vývoj mobilních aplikací v oblasti dopravy. Je navrženo komplexní řešení, které pokrývá všechny fáze vývoje aplikací, od sběru požadavků až po nasazení a další vývoj, s ohledem na specifické potřeby aplikací pro interní použití dopravců, které slouží jako mobilní podpora provozních informačních systémů. Metodika zohledňuje klíčové technické, právní a uživatelské požadavky a poskytuje strukturovaný postup, který optimalizuje čas, náklady a kvalitu výsledného produktu.

Navrhovaná metodika zahrnuje definici optimalizačních opatření zaměřených na urychlení vývoje, snížení nákladů, zlepšení kvality, zvýšení bezpečnosti a podporu flexibility a škálovatelnosti. Pomocí Checklandovy metodiky bylo vytvořeno pět variant systému vývojového procesu, které odpovídají prioritám projektu, jako jsou nejnižší náklady, nejrychlejší vývoj, nejvyšší kvalita, nejvyšší bezpečnost a flexibilita a škálovatelnost. Optimalizační opatření byla vyhodnocena pomocí metody vícekriteriálního rozhodování, implementována do příslušných variant a analyzována jejich účinnost. Jednou z hlavních předností práce je univerzálnost metodiky – přestože byla navržena pro návrh a vývoj aplikací pro interní použití u dopravců, které slouží jako mobilní podpora IS pro operativní řízení železniční dopravy, je adaptabilní i pro další specializované oblasti. Proces vývoje metodiky lze aplikovat na další projekty s nutností definovat nové klíčové parametry odpovídající dané oblasti, což umožňuje širší uplatnění a zvyšuje efektivitu na úrovni systému.

Praktické ověření metodiky na reálném projektu prokázalo její přínosy v podobě lepšího strukturování procesů, efektivnější komunikace v týmu a vyšší kvality výstupů. Zjištěné problémy, jako jsou zvýšené nároky na řízení subdodavatelů a administrativní zátěž spojená se standardizací, byly zohledněny jako zpětná vazba při konečných úpravách metodiky. Celkově

tato práce přispívá ke zlepšení procesu vývoje mobilních aplikací v oblasti dopravy a poskytuje užitečný rámec pro efektivní a systematický návrh softwarových řešení. Metodika je přínosem pro výzkumnou i praktickou komunitu a nabízí konkrétní kroky ke zlepšení kvality a efektivity softwarových projektů.

This dissertation deals with the design of a systematic methodology for the development of mobile applications in the field of transport. The author has created a comprehensive solution that covers all phases of application development, from requirements gathering to deployment and further development, considering the specific needs of applications for internal use by transport operators, serving as mobile support for operational information systems. The methodology reflects key technical, legal and user requirements and provides a structured process that optimises time, cost and quality of the final product.

The proposed methodology includes the definition of optimisation measures aimed at accelerating development, reducing costs, improving quality, enhancing security and promoting flexibility and scalability. Using Checkland's methodology, five variations of the development process system were created, corresponding to project priorities such as lowest cost, fastest development, highest quality, highest security, and flexibility and scalability. The optimisation measures were evaluated using a multi-criteria decision-making method, implemented in the respective variants and their effectiveness analysed. One of the main advantages of the work is the universality of the methodology - although it was designed for the design and development of applications for internal use by carriers, which serve as mobile support for IS for the operational management of railway transport, it is adaptable to other specialised areas. The process of developing the methodology can be applied to other projects with the need to define new key parameters corresponding to a given area, which allows for wider application and increases efficiency at the system level.

Practical validation of the methodology on a real project has demonstrated its benefits in terms of improved process structuring, more effective team communication and higher quality outputs. Confirmation of its benefits from the reference company is provided in Annex P. Challenges identified, such as increased demands on subcontractor management and the administrative burden of standardisation, were considered as feedback in the final adjustments to the methodology. Overall, this work contributes to improving the process of mobile application development in the transport domain and provides a useful framework for the efficient and systematic design of software solutions. The methodology is a contribution to both the research and practice communities, offering concrete steps to improve the quality and efficiency of software projects.