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THE IMPACT OF MOBILE APPLICATIONS ON BUSINESS ACTIVITIES

Specialty 122.02 Information Systems

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The thesis was developed within the Academy of Economic Studies of Moldova, AESM Doctoral School, Information Technology and Information Management Department.

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The PhD thesis and the abstract can be consulted at the Scientific Library of the Academy of Economic Studies of Moldova (G. Bănulescu-Bodoni St. 61, building F, Chișinău, MD-2005, Republic of Moldova), on the website of AESM (www.ase.md), and on the website of ANACEC (www.cnaa.md).

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1. CONCEPTUAL RESEARCH FRAMEWORK

The actuality and importance of the topic. Today's business environment is complex and competitive. Organizations, day by day, are increasingly forced to adjust their affairs and be more agile. In order to compete with the market, each company does research, development and improvement over their business model on a regular basis. This represents a lot of data to be collected and processed, due to this amount of work, in order to expand and automate they strongly rely on Information and Communication Technology (ICT) support. According to the report of Statista, there are reported over 5.44 billion ICT users [1] out of 8.17 billion global population. Combining business and technology, companies grow faster and plan more effective business strategies. Among these strategies and opportunities there are so called mobile applications marketplaces, a hot topic that gains auditory attraction in fast linear progression, due to the smartphone's penetration [2,3]. Mobile applications have become a cornerstone of modern business operations, driving significant impacts on customer engagement, operational efficiency, revenue generation, and market expansion. One of the most tangible values of mobile applications is their ability to enhance customer engagement. Considering the importance and wide use of mobile applications, the research on the topic of the thesis is particularly actual.

Degree of study of the problem. The subject regarding the impact of mobile applications was explored and researched by A. Holden [4], H. Heflin, J. Shewmaker, and J. Nguyen [5], Hala Alhodaib [6], K. Hahn [7], N. Akter [8], A.R. Altaleb [9], Grigore ULINICI [10] etc. Mostly all mentioned authors and others, touch the topic of mobile applications by solving a specific problem, but there is no described a deep study regarding the impact of mobile apps their selves. A majority of research papers touch mostly qualitative impact and do analysis via questionnaires and interviews, but there is lack of research parts like quantitative or measurable impact that could help businesses to improve their activities. Social or qualitative impact is important, but it is not all the time measurable. As well is observed that all researched topics target specific use cases and do not generalize a global formulation of the problem and propose generic solutions for solving or measuring the impact. Here comes the biggest challenge, most organizations want to enter into this environment and achieve new results, but there is small research and no clear understanding what impact will bring specifically mobile apps on business affairs.

The purpose of the research is the development of theoretical and practical aspects in perceiving the impact of mobile applications on business activities; analyzing and evaluating their impact on different types of business activities through mathematical modeling and computer simulation.

Research objectives. To achieve the defined scope, it is required to realize the following research objectives:

1) research and expend the knowledge base regarding the concept of the evaluation of mobile applications' impact in business activities;
2) identify the benefits of mobile applications in business activities;
3) categorize and classify mobile applications under different activity domains;
4) modeling the costs with mobile apps to be supported by an entity;
5) identify and systemize the legal aspect regarding mobile apps distribution and use;
6) identify techniques, methods, and indices to evaluate mobile apps benefits;
7) identify methods of evaluating the reasonability of investing in mobile apps.

Research hypothesis. In context of the research objectives, were made up several questions, and on their basis are formulated the following research hypotheses:

*Hypotheses 1***.** The mobile apps market growths and attract more and more users. This is why organizations have bigger interest and look for more benefits from mobile apps.

*Hypotheses 2***.** In order to find out the economic benefits from mobile apps, it is required to quantitatively measure them. Such measure of the impact of mobile apps will offer an opportune way to correctly decide in which apps it is reasonable to invest.

*Hypotheses 3***.** Legal point for mobile applications is important because knowing it helps to prevent lawsuit and mobile app store submissions.

Research methodologies and used methods. During the research process, all gathered information was obtained using direct and indirect studies. For this scope, were used a variety of classic research methods, like empiric observation, analysis (quantitative, qualitative, historical), ground analysis, dynamic reality analysis, synthesis, induction and deduction, methods of comparative analysis, logical analysis, computer simulation, as well as graphical and tabular overview of the studied materials. This collection of data was afterwards systematized and analyzed, using methods from statistics, mathematics and operational research.

The novelty and scientific originality of the work reside in:

1. The formulated research problem regarding the impact of mobile applications on business activities that could or even will face any organization or individual entrepreneur; the identified barriers and possible blockers that the mentioned entities could face.
2. The technology trends and recommendation list regarding the developing of a mobile application for supporting business activities.
3. The categorized benefices that mobile applications could provide.
4. The proposed set of indices to be used when defining the impact evaluation model.
5. Methods developed for evaluating the costs of mobile applications for many use cases.
6. The approaches for evaluating the reasonability of implementing mobile applications within organizations in different scenarios, including 24 formulated related optimization problems.

7. Developed impact models under different use cases of usage of mobile applications.
8. Elaborated legal checklist to be considered when deciding to submit or not a mobile application to mobile store not getting lawsuit.

The important scientific problem solved in the thesis: the systematization, definition, argumentation and proposal of solutions, including indices, techniques, models and optimization problems, to evaluate the impact of mobile applications in business activities and to streamline decisions regarding the development and implementation of such applications.

The theoretical importance and the applied value of the work. The proposed methodology and concrete optimization problems for the evaluation of the impact of mobile apps forms a solid base for future research in the domain. The obtained results are of particular practical interest for the business environment regarding the use of mobile applications. They help streamline your mobile app investment and improve your potential results.

Implementation of scientific results. The obtained scientific results were implemented by five economic agents, confirming the importance of the research theme and the applied value of the obtained results, namely: IMNA Solutions, Securer, VentureRocket, Ministry of Finance of the Republic of Moldova and User1st.

Approval of research results. The basic results of the thesis were discussed at 7 scientific conferences and were published in 11 papers, including 4 articles in four peer-reviewed scientific journals, three of which without co-authors; in total 8 publications without co-authors.

The volume and structure of the thesis. The thesis consists of: introduction, three chapters, general conclusions and recommendations, 8 annexes and 162 titles of bibliographic sources. The main part of the thesis is found on 120 pages.

2. THESIS CONTENT

2.1. Challenges for Measuring the Impact of Mobile Applications on Business Activities

Because mobile applications refer to the ICT one, there are some common aspects in the evaluation of mobile applications with the evaluation of ICT applications in general. At the same time, a generalized model or a template solution will not work over specialized ICT solutions like mobile applications.

Mobile applications can provide many benefits; they can be direct, indirect or both at the same time. These benefits could be qualitative and quantitative applied in different business activities. They can be considered as economic, social (or better called public) and research values, where:

1. Economic values can provide new sources of income, acquisitions, etc.

2. Social values can provide new direct communication channels, branding, reputation improvement, etc.

3. Research values can provide new market fields to be researched, better understand of customers' behavior, new areas to test product prototypes and organization strategies etc.

Today there are a lot of mobile devices that run different types of mobile applications. This list of mobile devices proofs that modern understanding is related more to the installed OS, rather than simply portability. Going from this point can be concluded a new definition for mobile devices: ***mobile devices are those smart devices that run on mobile OS specifically and can launch designed mobile applications under that OS***.

On a model level, every business activity is composed from series of inputs, intermediates and outputs. Generally speaking there are lots of software solutions researches based on evaluation economic impact of ICT, but these investigations are based on more like enterprise level organizations. Even though, there are a lot of challenges, barriers, limitations or even blockers from the private organization to share research results. All these remarks conclude that all the proposed models are more like limited and do not provide more concise results.

There exist a lot of methodologies for evaluating the impact of an ICT project. For more common approach, in the thesis were analyzed three main such approaches: portfolio, budget and project based. Usually enterprises are looking forward in all these three methods. In order to evaluate the impact of an ICT product it is required to understand the product needs and requirements, in simpler terms that means "What are the expectations from the product?". The breakdown of this point can be considered the following:

1. The purpose or general scope of the product.
2. The feature set which the product must include.
3. The use cases the product must cover.
4. The relation of product with existing or future products.

The topic regarding mobile apps impact on business activities was studied and analyzed by many researchers. Most researchers explored this subject under specific approach, meaning touching and trying to solve mostly one specific problem and touching the problem's domain origin. This means that they took a targeted use case related to a mobile app and how it can or could solve a business issue. In the thesis they are analyzed three research methods used and results published in [4-11], namely the Interview, Survey, and Scoring methods.

Interview method. The Interview method represents a classic form of qualitative research and, with refer to the topic in question, is used to collect information regarding the opinion of beneficiaries of mobile apps. In most studied cases, Interview method works only for enhancing mobile apps experience and understanding the need of the users. Going over researches that use the interview method [6-9], can be denoted that the main scope of the implementation of mobile apps is more related not to the measurable impact that they can provide, but to their adoption majority of a business or

organization. Investments without positive economic output cannot keep any business on long term.

Survey method. The Survey method is a widely used research approach that involves collecting data directly from respondents to gather insights on specific topics or trends. In [5,12,13] are described a wider exploration over the topic of mobile apps' impact. The offered by researchers' surveys target not only consumers (like simple apps users, employees, etc.), but as well organizations [13]. In the mentioned works are missing the quantitative analysis, especially the economic indices that reflect the impact of mobile apps themselves over different business activities.

Scoring method. In several works [4, 14], was observed the Scoring approach regarding the reasonability of using or implementing mobile app within an organization. This approach is considered practical and objective approach, but in order it to be validated it has to be argued. In this scope, it is required to be defined the indices that determine the impact of mobile apps on business activities, otherwise any business must invest separately in dedicated research in order to understand what are the required indices and how to score them.

From observations can be concluded the following affirmations:

1. There is an interest in topics related to business in relation with mobile applications and mobile devices.
2. All researches have within their works in common content like: a) mobile market situation during work period; b) mobile technology and frameworks; c) mobile development or how to develop a mobile application; d) mobile stores; e) statistics related between specific domain and mobile applications.
3. Most researches describe qualitative indices or better said the qualitative benefits the mobile applications can provide to business or organization.
4. Research methods are based on: a) researches are based on statistics and open-access reports offered by private agencies; b) use of interviews and surveys for trying to understand the impact of mobile application from a specific business activity; c) methods related to qualitative analysis;
5. Lack of: a) clear and keen description of methodologies, techniques or workflows how to evaluate impact of a mobile application within any business activity [11]; b) using the quantitative economic indices for the evaluating of the impact of mobile application on business activities.

The research problem

Measuring the impact of mobile apps on business activities for any organization does not represent an easy task. In order to understand and face the challenges of evaluation impact of mobile apps, it is required systemically research the economic value and the understanding of the investment part, analyze all the intermediates and at the end go over the outputs. To assess ICT investments, in case of mobile apps, groups of methods and models are conventionally distinguished (although many methods can be classified

into several categories at once) and systemized. As a result of the research done in previously, it can be denoted that mobile apps can have a considerable impact on economic and social level. At the same time those values that they can bring could impact not only the organization itself, but as well bring contribution to the society and economic growth at the country level, where the organization is based in. Like any other ICT solution, mobile apps bring their own value affecting in their manner any type of business activity. The impact of mobile apps on business activities must represent a particular interest for different private and public organizations. In order to fully understand the impact of mobile apps over business activities it is required to receive, analyze and adopt successful use cases. Model the successful strategy under the need of organization and, if it is possible, to provide academic insights for future researchers, in order to fulfill the topic, research and development.

Some expected results of the research in the field refer to:

1. The set of relevant criteria, classification and characteristics of categories of mobile applications in business support.
2. The quantitative and qualitative characteristics of the benefits from the implementation of mobile applications by category.
3. Technological trends to be used in mobile apps to support and develop businesses.
4. Models of strategies for implementing mobile apps in business by category.
5. Definition and analysis of the concept of use of mobile apps in support of business.
6. Identification and quantitative and qualitative characterization of the benefits from using mobile applications by category.
7. Analysis, elaboration and development of models of strategies for the implementation of mobile applications in business by category.
8. Estimating the impact of implementing some models of mobile application implementation strategies on the sustainability and performance of some businesses.
9. Recommendations regarding the development and differentiated systemic implementation of mobile applications within companies, depending on their profile, size, economic-financial status and the state of development of their IT infrastructure.
10. Recommendations regarding the development of the national legislative framework regarding the implementation of relevant mobile apps in business.

2.2. Measuring and Modeling the Impact of Mobile Applications on Business Activities

Measuring the impact of a product or service can be complex and multi-dimensional. Specific criteria and indices are needed for every business in order to understand the value of their investment and present important informative reports to investors, stakeholders or even themselves.

In order to understand the primary objectives, in the thesis were described the business activity domains, were made the mobile apps classification on their basis and were systemized the suitable business activities that can be covered by mobile apps.

Also, in order to determine any model, first of all is required to examine mobile application features and mobile application costs. Usually costs of mobile apps consist from development, delivery and maintenance. Considering that mobile app delivery consists in most cases by covering two platforms (Android & iOS), these can be analyzed in many use cases, because not every mobile application is designed only for public use and covering both platforms. These use cases are the following:

1. Mobile applications for internal use only (Cases):

a. Develop and use only an Android or an iOS mobile application.

b. Develop and use both an Android and an iOS mobile application.

2. Mobile applications for external use (Cases):

c. Develop and distribute only an Android or an iOS mobile application.

d. Develop and distribute both an Android and an iOS mobile application.

3. Mobile applications for internal and external use (Cases):

e. Develop, internal use and distribute only an Android or an iOS mobile app.

f. Develop, internal use and distribute both an Android and an iOS mobile app.

These six cases look similar and from first sight there is not difference, but in real life the costs are different. Each of Cases a.-f. is analyzed separately in the thesis. As an example, Case d. is shortly described below.

Case d. *Develop and distribute both an Android and an iOS mobile application*

For a developer (Case d.1), the needed total costs to develop, maintain and distribute both an Android and an iOS mobile application are determined as

$$2.4\sum_{k=1}^{4} H_{ki}R_k + \sum_{s=1}^{S} C_{si} + C_{Oi} + 2M_i, \qquad (2.1)$$

where: $C_i = \sum_{k=1}^{4} H_{ki}R_k + M_i$ is the cost of a mobile application i; H_{ki} is the total number of hours spent by employees of category k to develop the mobile application i; R_k is the rate per hour for an employee of category k; M_i are miscellaneous costs, such as licensing, 3rd party services, etc. with the mobile app i; $E_i = 0.2\sum_{k=1}^{4} H_{ki}R_k$ are maintenance costs, considered of around 20% of the initial development of mobile app i; $C_{Oi} \geq 0$ are iOS mobile app store costs for the mobile application i; $C_{si} \geq 0$ are Android mobile application store s costs for the mobile application i, and $S \geq 1$ is the number of Android mobile application stores to be supported.

Evidently, for a purchaser, the price I_i (investment) for an Android or an iOS mobile application i (Case d.2) is determined according to formula

$$I_i = (C_i + E_i)(1 + \text{PR}) = (1 + \text{PR})\left(1.2\sum_{k=1}^{4} H_{ki}R_k + M_i\right), \quad (2.2)$$

where PR is the established profit rate.

In order to understand what indicators to choose for evaluating the impact of mobile apps on a specific business affair, it is needed to determine first of all what type of impact is expected to achieve. When companies analyze what criteria to consider regarding the impact of mobile applications over their activity, in most of the cases they look over quantitative indices. But sometimes qualitative indices also play an important role.

Mobile applications are IT applications. A decision of investment in an IT project (i-project) is usually made on the basis of efficiency **quantitative indices**. For the assessment of economic efficiency of investment projects, in various sources is recommended to use such quantitative indices as: profit, profit rate [15,16], payback period on investment, net present value [15,17,18], profitability index [15,18,19], internal rate of return [15-17,19], return on investment [15,20], economic return on investments [16,20], adjusted expenditure [20], total costs of ownership [21] and so on.

From the multitude of indices, in [22] are selected and described 16, most commonly used for estimating the economic efficiency of i-products, namely: profit, profit rate, discounted return on investment (R_d), payback period on investments, updated payback period on investments, economic return on investments (general index of economic efficiency of investments) - R^{EI}, net value, net present value (NPV), internal rate of return (IRR), accounting rate of return, profitability index (PI), annual economic effect, annual adjusted expenditure, adjusted expenditure (C^{EN}), total cost of ownership (TCO) and annual average costs of ownership.

The comparative analysis, performed in [23] and based on correlation between indices, the specificity of the time value of money, the different duration of projects and also the range and importance of the characterized aspects, led to the reduction of the number of core indices for the comparative analysis of i-projects from 16 to 7, namely: R_d, R^{EI}, NPV, IRR, PI, C^{EN} and TCO, eventually in conjunction with the equivalent annual value (EAV) method.

Moreover, according to Statement 2 of [24], for projects, the revenues from the implementation of which can be estimated with reasonable efforts, the use of C^{EN}, TCO, R_d and R^{EI} indices as basic indices of economic efficiency is not appropriate. Thus, out of the 16 mentioned above, as basic indices, for projects the revenues from the implementation of which can be estimated with reasonable efforts, remained three: NPV, IRR and PI, eventually in conjunction with the EAV method, that is for project *i*:

$$\mathrm{NPV}_i = \sum_{t=\tau_i+1}^{L_i} \frac{\mathrm{CF}_{it}}{(1+d)^t} - I_i, i = \overline{1,n}, \tag{2.3}$$

$$\mathrm{PI}_i = 1 + \frac{\mathrm{NPV}_i}{I_i}, i = \overline{1,n}, \tag{2.4}$$

where n is the total number of considered mobile apps, d - the discount rate, I_i – total investment with the project, $L_i = \tau_i + D_i$ - the duration of the project, τ_i - the duration of the acquisition of investments (own development), D_i - the duration of the use of mobile application i, and CF_{it} - cash flows in year t.

The IRR for mobile application $i = \overline{1,n}$, i.e. IRR_i, is determined by solving the equation

$$\sum_{t=\tau_i+1}^{L_i} \frac{\mathrm{CF}_{it}}{(1+\mathrm{IRR}_i)^t} - I_i = 0, i = \overline{1,n}. \tag{2.5}$$

The EAV method [25] is used for the appropriate comparison of projects with different lifetimes. It puts in an adequate correspondence to the updated summary value over a period of time of an index of a value over a shorter period, e.g. one year, thus allowing comparative analysis of projects with different lifetimes of their products. It is based on the capital recovery factor (CRF), which represents the ratio between a constant annuity and the discounted value of the receiver of this annuity for a certain period of time. The CRF can be interpreted as the value to be received each year during the product use, so that the actual total value of all these equal payments is equivalent to one current monetary unit payment.

In case of discount rate d and duration of product use D, the CRF value at the start of the mobile application launch in exploitation is determined as [25]

$$\mathrm{CRF} = \left[\sum_{t=1}^{D} \frac{1}{(1+d)^t}\right]^{-1} = \frac{d(1+d)^D}{(1+d)^D - 1}. \tag{2.6}$$

From this formula, one has $\mathrm{CRF}(D{=}1) = d + 1$ and $\mathrm{CRF}(D{\to}\infty) = d$; thus, $d \le \mathrm{CRF} < d + 1$ [23]. For the index XX, which characterizes a certain absolute value for the entire period D, the equivalent annual value will be noted EAXX and is determined as

$$\mathrm{EAXX} = \mathrm{CRF} \times \mathrm{XX}. \tag{2.7}$$

If the EAV method applies to the NPV index, it is also called the equivalent annual cost method (EAC) [25]. For example, between EAC and CRF indices, occurs the relation

$$\mathrm{EAC} = \mathrm{EANPV} = \mathrm{CRF} \times \mathrm{NPV}. \tag{2.8}$$

Similarly:

$$\text{EAPI} = \text{CRF} \times \text{PI}. \tag{2.9}$$

Qualitative indices, compared with previously described quantitative indices, for mobile applications provide subjective yet vital measurements for assessing the overall user experience, ethical standing, and emotional engagement of an app. These indices help evaluate aspects that are difficult to quantify but essential for a comprehensive understanding of an app's impact on its users and how much users are engaged with it. Among the most common groups of indices are acquisition, engagement, monetization and retention indices described in the thesis.

Indices for measuring the impact by use cases

The quantitative indices, **NPV_i, IRR_i and PI_i for measuring the impact of mobile app *i*** in each of Cases a.-f. described above, are concretized separately for one beneficiary and one (Android or iOS, scenario $\{j = 1, n = 1\}$) or two (Android and iOS, scenario $\{j = 1, n = 2\}$) mobile apps. For example, for a developer in Case b. occurs $I_i = 2C_i$, where $C_i = \sum_{k=1}^{4} H_{ki}R_k + M_i$; thus are obtained (partially):

$$\text{NPV}_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+d)^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right); \tag{2.10}$$

$$\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right) = 0; \tag{2.11}$$

$$\text{PI}_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+d)^t} \Bigg/ 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right); \tag{2.12}$$

$$\text{EANPV}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i} - 1}\left[\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+d)^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right)\right]; \tag{2.13}$$

$$\text{EAPI}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i} - 1} \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+d)^t} \Bigg/ 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right), \tag{2.14}$$

where P_{it} is the profit and AA_{it} - the amortization in year t with refer to mobile application i.

Models for determining the impact of mobile applications

Sometimes, beneficiaries' available financial resources are not sufficient to invest in all opportune to use. In such cases it is needed to decide how much and in which of the needed applications to invest. This is why it is examined the related restrictions and use of available financial resources for investment in one or more mobile applications from the n in total by one beneficiary or by J beneficiaries. Suppose that the budget in this aim is B and for mobile application i ($i = \overline{1,n}$) is needed I_i financial resources. Also, it

is considered that the n mobile applications are sequenced in the order of their preference to invest. Sequencing can be done, for example, by each beneficiary itself by comparing in pairs the mobile applications using the indices for measuring the impact.

Model one beneficiary has to invest in mobile applications

Let a beneficiary has a budget B to invest in all or some of the n mobile applications in total in conditions that for mobile application i ($i = \overline{1,n}$) is needed I_i financial resources. It may be that budget B is not sufficient to invest in all n mobile applications. Let note as N_o is the set of mobile applications selected for investment. Then it is mandatory to satisfy the restriction

$$\sum_{i \in N_o} I_i \leq B. \tag{2.15}$$

One of the simple ways to find the quasi optimal set N_o is the following. Assume that the n mobile applications are sequenced (by the beneficiary j itself, for example) in the order of preference to be included in the set N_o. Without reducing the universality of the approach, it is considered that this is the sequence $i = \overline{1,n}$. Then a simple algorithm - **Algorithm 2.1**, for determining the set N_o is the following:

1º. $i := 1$. $R := B$, $N_o := \varnothing$.

2º. If $I_i \leq R$, then $N_o := N_o \cup i$, $m := i + 1$, $R := R - I_i$.

3º. If $i < n$, then $i := i + 1$ and go to Step 2º.

4º. Stop.

Of course, there are many more complex algorithms for determining the set N_o. Some of them are described in the thesis. The total impact of the selected set N_o of mobile apps can be determined by calculating the values of NPV, IRR, and PI indices, eventually in conjunction with the EAV method.

Model many beneficiaries have to invest in many mobile applications

Restriction (2.15) is convenient for one beneficiary that will desire one or more mobile applications. For the case when there is a budget intended for more beneficiaries that have to invest in one or more mobile applications, it is needed to adjust the restriction and add as well conditional distribution among beneficiaries [26]. Let's suppose that each beneficiary j will get B_j financial resources from B to invest in the set N_j of mobile applications from the set N in total, i.e. $N_j \subseteq N$, and $| N | = n$. This distribution of B among the J beneficiaries can be done, for example, by weights W_j, $j = \overline{1,J}$, where $0 \leq W_j < 1$ and $\sum_{j=1}^{J} W_j = 1$. Then one has:

$$B = \sum_{j=1}^{J} B_j; \quad B_j = \sum_{j=1}^{J} W_j B, j = \overline{1,J}; \tag{2.16), (2.17}$$

$$G_j = \sum_{i \in N_j} I_i, j = \overline{1,J}; \qquad G = \sum_{j=1}^{J} G_j \qquad (2.18), (2.19)$$

when compliant with the restrictions

$$G_j \le B_j, j = \overline{1,J}, \qquad (2.20)$$

where I_i is the investment needed for mobile application i ($i = \overline{1,n}$), G_j - the investment needed to beneficiary j for the set N_j of mobile applications, and G - the total investments needed for the all J beneficiaries.

Of course, because of restrictions (2.9), it occurs

$$G \le B. \qquad (2.21)$$

At the same time, because of discrete character of I_i, $i = \overline{1,n}$ values, in relationship (2.21) usually occurs $G < B$. Thus, it remains $R = G < B$ of unused budget B and it is opportune to redistribute the budget B among the J beneficiaries, but not reducing the G_j, $j = \overline{1,J}$ values. For this, it can be used different scenarios. One rational of them is the described below.

Without reducing the universality of the approach, suppose that from the beginning they take place the relationships $W_1 \ge W_2 \ge W_3 \ge \ldots \ge W_n$. For each beneficiary j, the mobile application of the set $H_j = N \backslash N_j$ are sequenced (by the beneficiary j itself, for example) in the order of preference to be added to the set N_j, let it be the sequence j_k, $k = \overline{1, |N \backslash N_j|}$. Then the algorithm - **Algorithm 2.2,** of distributing the part R of budget B among the J beneficiaries is the following:

1°. $j := 1$. $k := 1$.

2°. $u := j_k$. If $I_u \le R$, then $N_j := N_j \cup u$, $m_j := u + 1$, $R := R - I_u$ and go to Step 4°.

3°. If $k < N \backslash N_j$, then $k := k + 1$ and go to Step 2°.

4°. If $j < J$, then $j := j + 1$, $k := 1$ and go to Step 2°.

5°. If $R < \min\limits_{j=\overline{1,J}} \left\{ \min\limits_{k=\overline{m_j, |N \backslash N_j|}} \{I_{j_k}\} \right\}$, then Stop.

6°. $j := 1$.

7°. If $m_j > |N \backslash N_j|$, then go to Step 9°.

8°. $k := m_j$ and go to Step 2°.

9°. If $j < J$, then $j := j + 1$ and go to Step 7°.

10°. Stop.

Some commentaries to the algorithm. Steps 2°-4° realize one round of adding by one new mobile application to those beneficiaries from the J, in the order of weights W_j, $j = \overline{1,J}$, which satisfy the condition $I_u \le R$. In their turn, Steps 6°-9° select the beneficiaries candidates for a new round of adding by one mobile application. The algorithm stops when there is no one mobile application i with $I_i \le R$ to add to any of the J beneficiaries – Steps 5° and 10°.

Of course, there are many more complex algorithms for determining the set N_o. Some of them are described in Section 3.3.5 of the thesis.

The total impact of the selected mobile applications for each beneficiary and also for all J beneficiaries can be determined by calculating the values of NPV, IRR, and PI indices, eventually in conjunction with the EAV method.

Social impact

Besides the quantitative indices, most of them being important for measuring the economic value of mobile application on business activities, there are as well so called "Social Values". It was mentioned that there is a big audience in social part of media users [1], among them due high preference [2] they tend to use a mobile device, rather than a stationary PC or a portable laptop due to preferences, price, affordability and portability. Generally speaking of mobile devices and mobile applications, if to put aside the economic values for business, it has huge influence or even impact over people in the last decade. This impact as well indirect or direct influences a majority of existing businesses. In other words, from a business perspective where is interest there is an auditory and there should be a demand for something, that could be sold. The penetration of this focal interest point can be considered as an impact. Most users, from mobile perspective in a social impact point of view, use them for: Social networking, improving quality of life day by day, portable source of information, and portable instrument for optimizing daily tasks within business activities. Each item nominated item affects or contributes directly or indirectly to existing business activities.

2.3. Evaluating the Impact of Mobile Applications on Business Activities

Mobile application can be developed under any scope, feature desires and design in the limit of technical possibilities. Unfortunately, in order to distribute them to public or a closed group there will be a set of requirements. These requirements can be established by the mobile stores, government or both. Mobile stores policies are defined:

1. For Google Play Store is Google Play Developer Policy Center.
2. For Apple App Store is App Store Review Guidelines.

Regarding government, this depends individually where the mobile application will be distributed, for what countries or zones. Among the enforcement set by mobile stores, there are as well numerous legal considerations that developers, businesses, and entrepreneurs must address to ensure compliance with local and international laws. These legal aspects are examined and systemized in the thesis.

Software development methodologies (Traditional, Agile, Spiral, and Personal Software Process) are also examined and systemized in the thesis.

From the multitude of scenarios that can lead future beneficiaries to take the decision regarding the implementation of mobile apps, three will be examined in the following:

1) consideration of a specific mobile application;

2) selection of one or more mobile applications from a particular set at given financial resources;
3) selection of one or more mobile applications from a specific set simultaneously with other potential investment projects at given financial resources.

In the last two scenarios, the selection of investment projects is carried out by comparing in pairs based on the values of the impact criteria when implementing the projects. The quantitative criteria for comparing the various projects will be NPV, IRR and PI, eventually in conjunction with the EAV method. In this context, it is important to mention that the NPV, IRR and PI indices form a Pareto set: no one of the three can always replace the use of one or two of the other indices, in sense of obtaining the same solutions when comparing investment projects. At the same time, there are particular cases when the use of two or of the all three indices, for comparing two investment projects, leads to the same solution. It is of interest how frequently such cases take place. The respective aspects for projects with equal lifetimes are researched in [27] and in IT projects with different lifetimes are examined in [28,29].

Considering a specific mobile application

When considering a specific mobile application, the beneficiary has to calculate the values of the NPV, IRR and PI indices and, optionally, of the other quantitative indices, using initial data referred to two alternatives:

a) procurement of the mobile application in question;
b) own development of the mobile application in question.

Also, when taking the decision, it has to consider the qualitative criteria of interest.

Comparing two mobile applications with different lifetimes

When comparing mobile applications with different lifetimes, as basic quantitative criteria it is reasonable to use the NPV, IRR and PI indices in conjunction with the EAV method, i.e. EANPV, IRR and EAPI indices. Usually it is important to at what extent the use of these indices is better than the use of the NPV, IRR and PI ones.

Let's compare two projects (mobile applications), 1 and 2, the revenues from the implementation of which can be estimated with reasonable efforts. Then, at $NPV_1 > 0$ (projects with $NPV < 0$ are not eligible) and the pairwise comparison of the three indices for Projects 1 and 2, it was found that [24]:

1) the use of EAPI and IRR indices leads to the same solution, being preferable the project 1, in the following two cases: (a) $IRR_1 > d \geq IRR_2$; (b) $D_2 \geq D_1$, $IRR_1 > IRR_2$, $CF_{1t} = CF_1$, $t = \overline{1, D_1}$ and $CF_{2t} = CF_2$, $t = \overline{1, D_2}$;

2) the use of EAPI and EANPV indices leads to the same solution, being preferable the project 1, if $EAPI_1 = EAPI_2 + \beta$, $\beta > 0$ and

$$\beta > I_2^C (EAPI_2 - CRF_2) / I_1^C - (EAPI_2 - CRF_1);$$

3) the use of EAPI and EANPV indices leads to different solutions if $I_1^C > I_2^C$, $EAPI_1 = EAPI_2 + \beta$ and $\beta < I_2^C(EAPI_2 - CRF_2)/I_1^C - (EAPI_2 - CRF_1)$.

But these results do not fully characterize the opportunity of using one or another index when comparing investment i-projects. There may be cases when the use of NPV, IRR and PI indices in conjunction with the EAV method leads to different solutions. For comparative analysis of projects with unequal lives, in [28] a special model is proposed. The examined problem is the following. They are compared two investment projects, 1 and 2, with different lifetimes $D_1 > D_2$. When updating the values of indices, as time reference point will be the projects launch in operation; this time is the same for Projects 1 and 2. It is required to identify, by computer simulation, the percentage of cases when the solutions, obtained using indices of each of the pairs NP = {NPV, PI} – q_{NP}, NR = {NPV, IRR} – q_{NR}, PR = {PI, IRR} – q_{PR}, NPE = {EANPV, EAPI} – q_{ENI}, NRE = {EANPV, IRR} – q_{ENR}, and PRE = {EAPI, IRR} – q_{EPR}, leads to different solutions. The NPV, PI, IRR, EANPV and EAPI values are determined according to formulas (1)-(5). The discount rate d will be considered constant and equal for the two projects, but the values of CF_t and also those of I and D can be different for the two projects.

Considering data from [30], in [28] is shown the reasonability to use the **discount rate $d \in$ [0.05; 0.14].** With refer to the value of **internal rate of return IRR = r**, considering data from [31] in [28] is shown the reasonability to use the range **$r \in$ [0.1; 1].** In calculations, for the duration D of investment projects are used values in the range of [1; 10] stages (years, etc.), that is $D \in$ [1; 10], and for the investment I – in the range of [100; 1000] conventional units, that is $I \in$ [100; 1000].

Using these initial data, seven groups of alternatives for computer simulation are selected, including: Group 1 - dependence on d; Group 2 - dependence on D_2; Group 3 - dependence on I_2; Group 4 - dependence on r, Group 5 - dependence on v, Group 6 - dependence on d+ and Group 7 - *dependence* on d· (the general group). In all of them, the CF_t values are generated randomly at uniform distribution. For each of the seven alternatives, the respective percentages q_{NP}, q_{NR}, q_{PR}, q_{NPE}, q_{NRE}, and q_{PRE} were determined using the SIMINV computer application. When simulated, for each final point of results a sample of 100000 sets of initial data were generated. So, for the 7 groups of alternatives, a total of 20 mln sets of initial data were generated. Some of the obtained results are described below.

Example - using IRR and PI indices. Initial data common to both projects (1 and 2): $d = 0.1$. Project 1 is characterized by the data: $D_1 = 7$, $I_1 = 125.7$, $CF_{1,1} = 81.6$, $CF_{1,2} = 44.3$, $CF_{1,3} = 40.4$, $CF_{1,4} = 78.4$, $CF_{1,5} = 63.3$, $CF_{1,6} = 39.7$, $CF_{1,7} = 42.7$. Also, Project

2 is characterized by the data: $D_2 = 6$, $I_2 = 609.0$, $CF_{2,1} = 206.8$, $CF_{2,2} = 407.0$, $CF_{2,3} = 250.2$, $CF_{2,4} = 305.0$, $CF_{2,5} = 412.6$, $CF_{2,6} = 385.5$.

The results of calculations for indices IRR and PI are: $PI_1 = 2.214$, $PI_2 = 2.290$, $IRR_1 = 0.450$ and $IRR_2 = 0.436$. So: $PI_1 = 2.214 < PI_2 = 2.290$ and $IRR_1 = 0.450 > IRR_2 = 0.436$. Thus, the solutions obtained differ: according to the IRR index, one has to prefer the Project 1, but according to the PI index, one has to prefer the Project 2. This confirms the fact that the use of IRR and PI can lead to different solutions.

The group of alternatives 2 - dependence on D_2. Initial data: $d = \{0.05, 0.06, 0.07, \ldots, 0.14\}$; $D_1 = 10$, $D_2 = \{1, 2, 3, \ldots, 9\}$; $I_1 = 1000$, $I_2 = 500$; $r = 0.2$; $v = 0.5$. In graphical form, the dependences $q_{NP}(D_2)$, $q_{NR}(D_2)$, $q_{PR}(D_2)$, $q_{NPE}(D_2)$, $q_{NRE}(D_2)$ and $q_{PRE}(D_2)$ at $d = 0.08$ are shown in Figure 2.1.

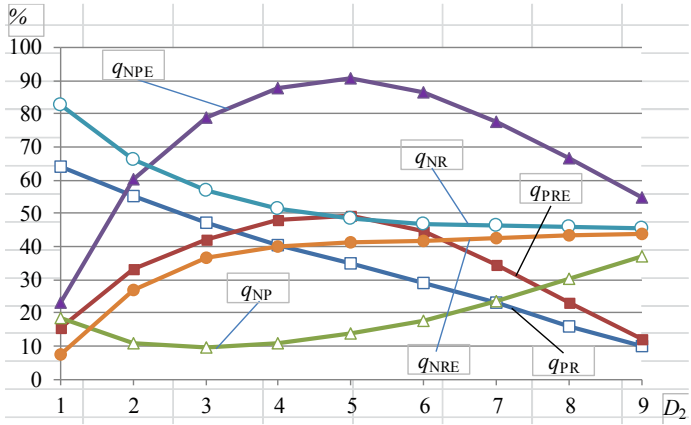

Figure 2.1 Percentages $q_{NP}(D_2)$, $q_{NR}(D_2)$, $q_{PR}(D_2)$, $q_{NPE}(D_2)$, $q_{NRE}(D_2)$ and $q_{PRE}(D_2)$
***Source*:** elaborated by the author

According to Figure 2.1, the character of the six dependences on D_2 are different: that of $q_{NRE}(D_2)$ is increasing; those of $q_{NPE}(D_2)$ and $q_{PRE}(D_2)$ initially are increasing and after are decreasing; that of $q_{NP}(D_2)$ is decreasing at $D_2 \leq 3$ and is increasing at $D_2 > 3$; those of $q_{NR}(D_2)$ and $q_{PR}(D_2)$ are decreasing. Also, by pairs, the largest discrepancy is between $q_{NP}(D_2)$ and $q_{NPE}(D_2)$. At the same time, one has $q_{NP}(D_2) < q_{NPE}(D_2)$, $q_{NR}(D_2) > q_{NRE}(D_2)$, but $q_{PR}(D_2) > q_{PRE}(D_2)$ at $D_2 \leq 3$ and $q_{PR}(D_2) < q_{PRE}(D_2)$ at $D_2 > 3$.

It can be seen that there can be a large number of cases when the use of EANPV and EAPI indices leads to different solutions, which, on average, can reach 93.61%, this being approx. equal to the $q(d)$: $\max\{q_{NPE}(d)\} = 93.67\ \% \approx \max\{q_{NPE}(D_2)\} = 93.61\%$. The use of other pairs of compared indices also can lead to different solutions in a significant number of cases. The largest range is that of $q_{NPE}(D_2)$ equal to 93.61 – 13.18

= 80.43% ($q_{NPE}(D_2) \in [13.18; 93.61]$%), and the narrowest range is that of $q_{NP}(D_2)$ equal to 37.50 – 3.38 = 34.12% ($q_{NR}(D_2) \in [3.38; 37.50]$).

Thus, the use of EANPV and EAPI indices to compare projects with unequal lives not only allows a more accurate estimation of projects' efficiency, but also the solutions obtained may differ more frequently than when using NPV and PI indices. Usually, this statement is also valid for the pairs of indices {EAPI, IRR} and {PI, IRR}, but is an inverse one for the pairs of indices {EANPV, IRR} and {NPV, IRR}.

So, when comparing mobile applications with different lifetimes, the beneficiary has to calculate the values of the EANPV, IRR and EAPI indices and, optionally, of the other quantitative indices, using initial data referred to two alternatives:

a) procurement of the compared mobile applications;

b) own development of the mobile applications in question.

Also, when taking the decision, it can consider the qualitative criteria of interest.

One beneficiary which needs many mobile applications

A simple approach of this scenario is considering that preferences of investment in different mobile applications are known. Below are examined a more complex approach. Because of Pareto set of NPV, PI and IRR indices, in case of selection of many mobile applications with NPV > 0 and PI > 0 and limited financial resources, one has to use a specific optimization problem. For such a problem, may be many scenarios, determined by the used optimization criteria and restrictions. Some of such scenarios that can be of interest are:

a) use as optimization criterion of one of the NPV, PI and IRR indices and as restrictions – the limit values for financial resources and NPV, PI and IRR indices, eventually in conjunction with the EAV method;

b) use as optimization criterion of a synthetic index determined by pondering the NPV, PI and IRR indices and as restrictions – the limit values for financial resources and the NPV, PI and IRR indices, eventually in conjunction with the EAV method.

By using the scenario (a) can be formulated three different optimization problems, and when using the scenario (b) can be formulated many optimization problems that differ by the used pondering coefficients for the NPV, PI and IRR indices. In the last case one can consider one optimization problem, but with possible different values for the used pondering coefficients for the NPV, PI and IRR indices. In the thesis, there are formulated 24 such optimization problems. Two of them are described below.

Problem 3.1 (the number is the one from the thesis). Let it be a beneficiary who has B financial resources (budget) to invest in mobile apps. The selection is made from n mobile applications that have the characteristics: d, D, I_i, CF_{it}, $i = \overline{1,n}$, $t = \overline{1,D}$. It is required to select from these n a subset of mobile applications that would provide

$$\text{NPV} = \sum_{i=1}^{n} a_i \, \text{NPV}_i = \sum_{i=1}^{n} a_i \sum_{t=1}^{D} \left[\frac{\text{CF}_{it}}{(1+d)^t} - I_i \right] \to \max, \tag{2.22}$$

upon compliance with the restrictions

$$\sum_{i=1}^{n} a_i \, I_i \le B, \tag{2.23}$$

$$\text{NPV}_i = \sum_{t=1}^{D} \left[\frac{\text{CF}_{it}}{(1+d)^t} - I_i \right] \ge \text{NPV}_0, i = \overline{1,n}, \tag{2.24}$$

$$\text{PI}_i = \frac{1}{I_i} \sum_{t=1}^{D} \left[\frac{\text{CF}_{it}}{(1+d)^t} \right] \ge \text{PI}_0, i = \overline{1,n}, \tag{2.25}$$

$$\text{IRR}_i \ge \text{IRR}_0, i = \overline{1,n}, \tag{2.26}$$

where: a_i is a Boolean variable that takes the value 1 if project i is selected and the value 0 otherwise, NPV_0 – the minimum allowed value for NPV_i, PI_0 – the minimum allowed value for PI_i, and IRR_0 – the minimum allowed value for IRR_i, $i = \overline{1,n}$.

Because all components in restrictions (2.24)-(2.26) are known, the Problem 3.1 can be simplified by selecting from the n the mobile applications that satisfy these restrictions. Let's note the number of admitted mobile application also by n (a new value). Then the problem (2.22)-(2.26) is reducing to the {(2.22), (2.23)} one, but with a new n.

Model many beneficiaries which need many mobile applications

Let for the mobile application i ($i = \overline{1,n}$) it is needed I_i financial resources.

Problem 3.12 (the number is the one form the thesis). Let J beneficiaries have a common budget B to invest in mobile apps. The selection is made from n mobile applications that have the characteristics: d, D, I_i, CF_{jit}, $j = \overline{1,J}$, $i = \overline{1,n}$, $t = \overline{1,D}$. It is required to select from these n a subset of mobile applications that would provide

$$\begin{aligned} \text{NPR} &= \sum_{j=1}^{J} \sum_{i=1}^{n} a_{ji} \left(p_{1j} \text{NPV}_{ji} + p_{2j} \text{PI}_{ji} + p_{3j} \text{IRR}_{ji} \right) = \\ &= \sum_{j=1}^{J} \sum_{i=1}^{n} a_{ji} \left(p_{1j} \sum_{t=1}^{D} \left[\frac{\text{CF}_{jit}}{(1+d)^t} - I_i \right] + \frac{p_{2j}}{I_i} \sum_{t=1}^{D} \left[\frac{\text{CF}_{jit}}{(1+d)^t} \right] + p_{3j} \text{IRR}_i \right) \to \max, \end{aligned} \tag{2.27}$$

under compliance with the restrictions

$$\sum_{j=1}^{J} \sum_{i=1}^{n} a_{ji} \, I_i \le B, \tag{2.28}$$

$$\mathrm{PI}_{ji} = \frac{1}{I_i}\sum_{t=1}^{D}\left[\frac{\mathrm{CF}_{jit}}{(1+d)^t}\right] \geq \mathrm{PI}_0, i = \overline{1,n}, \tag{2.29}$$

$$\mathrm{IRR}_{ji} \geq \mathrm{IRR}_0, i = \overline{1,n}, \tag{2.30}$$

$$\mathrm{NPV} = \sum_{j=1}^{J}\sum_{i=1}^{n} a_{ji}\,\mathrm{NPV}_{ji} = \sum_{j=1}^{J}\sum_{i=1}^{n} a_{ji}\sum_{t=1}^{D}\left[\frac{\mathrm{CF}_{jit}}{(1+d)^t} - I_i\right] \geq \mathrm{NPV}_{\mathrm{tot}}, \tag{2.31}$$

where $\mathrm{NPV}_{\mathrm{tot}}$ is a constant and for $j = \overline{1,J}$, $i = \overline{1,n}$: a_{ji} is a Boolean variable that takes the value 1 if project i is selected for the beneficiary j and the value 0 otherwise; NPV_{ji} – the NPV value obtained by beneficiary j when investing in mobile application i; NPV_0 – the minimum allowed value for NPV_{ji}; PI_{ji} – the PI value when beneficiary j invests in mobile application i; PI_0 – the minimum allowed value for PI_{ji}; IRR_{ji} – the IRR value when beneficiary j invests in mobile application i; IRR_0 – the minimum allowed value for IRR_{ji}; p_{1j}, p_{2j}, p_{3j} are established weights coefficients for the NPV_{ji}, PI_{ji} and IRR_{ji} indices, respectively.

Because all components in restrictions (2.29) and (2.30) are known, the Problem 3.12 can be simplified by selecting from the n the mobile applications that satisfy these restrictions. Let's note the number of admitted mobile application also by n (a new value). Then the problem {(2.27)-(2.31)} is reducing to the {(2.27), (2.28), (2.31)} one, but with a new n.

Use Cases

The research results of the thesis are implemented within five organizations, namely IMNA Solutions, Securer, VentureRocket, Ministry of Finance of the Republic of Moldova and User1st, confirmed by respective certificates of implementation. As an example, the use case of IMNA Solutions is shortly described below.

IMNA Solutions use case

IMNA Solutions is a private technology company that specializes in developing innovative solutions aimed at enhancing healthcare delivery and patient management.

Problems faced. IMNA Solutions, like any other start-up tries to conquer the market and offer solutions that would help to solve different problems in healthcare. Among the most critical problems that IMNA observed while discussing with different healthcare institutions were:

1. Data inconsistency from different patients, doctors, records, etc.
2. Communication issues between patients and doctors.
3. Patients often do not update their medical data.

4. Patients and doctors are not updated in real-time with all the events that are happening.
5. Patients are often dropping trials and do not complete medical questionnaires.

Proposed solutions. Among the proposed solutions there was regarding mobile applications that were discussed, planned, developed and delivered in the end. The mobile applications were developed using native mobile frameworks due to security, data privacy and smart devices connection concerns.

Results. After the delivery of the mobile applications, IMNA Solutions obtained the following results:

1. Clinical institutions started to receive more accurate data from patients and the smart devices that were worn.
2. The communication issues between doctor and patients started to disappear. They became more often and more proactive, this part was sensed the most during the COVID19 period.
3. Patients began to complete more often medical questionnaires and reach the end of medical trials:

a. According to internal reports from Nasus Pharma [32], after using IMNA mobile application, one of their last medical trials out of 1000 people it ended with 100% user engagement (before the using IMNA mobile application, it was recorded at maximum of 72% user engagement).

b. According to internal reports from RambamHealth [33], after using IMNA mobile application, one of their last medical trials out of 200 people it ended with 98.5% user engagement (before the using IMNA mobile application, it was recorded at maximum of 67% user engagement).

Based on the available information and shared financial data, the model „one mobile application and one beneficiary" is analyzed.

Net Present Value. In order to simplify the final result for analysis will be used formula (2.3) adjusted according to offered economic data from IMNA Solutions. According to provided aggregated financial data were determined the cashflows for mobile applications. These are systemized in Table 2.1.

Table 2.1 IMNA Solutions Cashflows for mobile apps in the period 2014-2019

Year	Income (USD)	Costs (USD)	Net Cashflows (USD)
2014	4320	7920	-3600
2015	4440	7944	-3504
2016	5184	6900	-1716
2017	5400	7674	-2274
2018	5760	7932	-2172
2019	5844	8034	-2190

Source: developed by the author based on data from IMNA Solutions

According to the data in Table 2.1, at the initial investment of 66000 USD and the discount rate of 10%, at the time of launch of the set of mobile apps in operation (early 2014), the NPV value for the period 2014-2019 is obtained as approx. -71596 USD. As for the IRR value, it cannot be calculated because all cash flows over the six years are negative. Likewise, the value of the profitability index is obtained by approx. -0.19. Thus, the company IMNA Solutions suffered losses in the period 2014-2019.

Table 2.2 IMNA Solutions Cashflows for mobile apps in the period 2020-2022

Year	Income (USD)	Costs (USD)	Net Cashflows (USD)
2020	5928	7806	-1878
2021	17040	8508	8532
2022	29040	15222	138118

Source: developed by the author based on data from IMNA Solutions

According to the data in Table 2.2, at the initial investment of 72000 USD and the discount rate of 10%, at the time of the release of the set of mobile applications in operation (early 2020), the NPV value for the period 2020-2022 is obtained about 37114 USD. Regarding the IRR, its value is approx. 26.55%. Likewise, the value of the profitability index (PI) is obtained by approx. 1.52. Thus, the company IMNA Solutions in the period 2020-2022 incurred a significant profit. Of course, the experience gained in previous years also contributed to this result, as well as the contingent of customers that gradually formed.

GENERAL CONCLUSIONS & RECOMMENDATIONS

1. It is described the evolution of mobile devices and the appearance of mobile apps on the market. It was noticed that mobile apps are considered similar to any other ICT solution, but with their own specifications and environment.
2. It is argued the importance of mobile apps in the current market and its potential economic growth in different domain areas.
3. It is identified that most mobile stores, especially Google Play Store and Apple App Store, do not tend to standardize the mobile market regarding mobile apps categories and each one provides its own classification.

4. It is identified that the information, research and analytical data regarding the impact of mobile apps on business activities in a quantitative manner is poor; many organizations lack indices and criteria for measuring the quantitative impact of mobile applications on their business activities. The impact of mobile apps on business activities was discussed by many researchers, but they didn't provide a set of indices, methods, classifications, and techniques for the quantitative evaluation of their real impact.

5. The hypotheses of the research formulated in the Introduction section were validated.

6. The general systemic research problem is formulated and the objectives regarding the impact of mobile apps on business activities were defined.

7. It was proposed a list of technical recommendations and walkthrough the mobile apps technology stacks that will allow organizations to asses and better understand their needs and fit under their technological profile.

8. It is identified that the existing definitions of mobile devices and mobile apps are outdated and was proposed a new version for mobile devices' definition.

9. They are systemized the benefits that mobile apps can offer and as well how to measure them. They are described methods how to achieve the benefits measurements and at what stages to implement the analytics to gather data about them. This will guide organizations to understand the reasonability of their investments.

10. It is introduced the relationship between different economic activities domains and their connection to mobile application domains. As well it was proposed a guideline for organizations to understand where their business domain activity can fit with what mobile application domain.

11. They are introduced and classified strategies that many companies use for mobile application revenue gain, that are not directly based with their main economic activities. This should aid organizations to promote and generate new types of income.

12. They are defined how to evaluate costs and were defined criteria and indices for measuring the impact of mobile apps on business activities. The costs measure guidelines provide a clear understanding on the budget level if to go for internal development of mobile apps or simply purchase existing solutions.

13. They are proposed the restrictions to be taken into consideration when using the impact models. The restrictions will help organizations to secure their budget and better understand their investments on different phases of the project in question.

14. They are elaborated two models based on selected criteria and indices to measure the impact of mobile apps. These models were adjusted under different use cases.

15. It is described the social impact that mobile apps can bring on business activities.

16. Based on observations over mobile app stores policies it is concluded that, if the organization wants to make public a mobile application, it must be compliant in many aspects, starting with local laws and ending to the target zone legal aspect. In this context, it was described and systemized the legal point of view for releasing to public a mobile application. This part should serve as a guideline for any organization or individual entrepreneur and should help them pass the mobile store submission process and to avoid lawsuits and not violate the most important regulations.

17. They are described and systemized the technics for evaluating the development of mobile apps. These techniques will help organizations to understand the need of mobile app and if to develop it in-house or purchase a ready-on solution.

18. They are defined and examined the approaches for evaluating the reasonability of implementing a mobile applications within organizations, including such scenarios as: a) considering a specific mobile application; b) comparing two mobile apps with equal lifetimes; c) comparing two mobile apps with different lifetimes; d) one beneficiary which needs many mobile apps (there were defined 8 different related optimization problems); e) many beneficiary which need many mobile apps (there were defined 16 different related optimization problems).

By computer simulation, it was identified that when comparing mobile apps: (a) with equal lifetimes the solutions obtained by using the NPV, PI and IRR indices, does not coincide in more than 1/3 of cases; (b) with different lifetimes the use of the IRR index together with the EANPV and EAPI indices may influence the decision in, on average, of no more than 12.33% of cases. These are important aspects to be taken into consideration by any organization or individual entrepreneur when making a decision on investment to do.

19. The research results of this thesis are implemented within different organization. Some of them are described within the five use cases: IMNA Solutions, Ministry of Finance of the Republic of Moldova, Securer, VentureRocket, and User1st, and their implementations are confirmed by related certificates (see Annexes 4-8 of the thesis). The implementation of mobile apps had a significant economic and social impact. For example, with refer to IMNA Solutions, the investments in mobile apps led to the growth of the Net CashFlow from -$1878 in 2020 to $138118 in 2022. At the same time, the implementation of mobile apps within Securer led to the growth of the number of active users by 12%, and within VentureRocket - to the growth of the number of active users by 9%.

As a result of the scientific and applied research on the topic of the thesis, it is recommended:

1. To higher education institutions with study programs in the fields of ICT and economics - the use of methods of analysis and evaluation of the impact of mobile apps on business activities within the curriculum of some university courses.
2. To economic agents from various fields of activity:
   a) quantitative and qualitative analysis of the impact of currently used mobile applications and evaluation of the potential impact of the implementation of new mobile applications for the efficiency of activities;
   b) studying the national and international legal framework and the requirements of stores, related to the development and placement of mobile applications in stores, in order to comply with their stipulations.
3. For researchers, PhD students, students - the following possible directions for future research in the field:
   a) specifying and completing the initial statistical data necessary to determine the impact of mobile applications on business activities;
   b) creating and simulating new impact measurement models for mobile functionalities within a specific business activity;
   c) adjusting and adding new variables to the modeling restrictions to match current market changes;
   d) researching and sharing more results on the topic of this thesis, to help or interest other researchers to participate with research in this field.

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2. Articles in scientific journals

2.2. in journals from other databases accepted by ANACEC (indicating the database)

1. BOLUN, Ion, GHETMANCENCO, Svetlana, NASTAS, Vasile. ***Equivalent annual value method's influence on the selection of IT investment projects.*** In: *Journal of Business and Economics*, October 2022, Vol. 13, No. 10, pp 555-569. c.a. 1,3. ISSN 2155-7950. Available: https://portal.issn.org/resource/.

2.3. in journals from the National Register of journals under profile (indicating the category)

2. NASTAS, Vasile. ***Automation of the know your customer processthrough the mobile application,*** **2022,** In: *Revista Economica*, 2022, nr.3(121), pp. 104-115, c.a. 0,62. ISSN 1810-9136. DOI: https://doi.org/10.53486/econ.2022.121.104. Categoria B. Available: *https://ibn.idsi.md/ro/vizualizare_articol/169531.*

3. NASTAS, Vasile. ***Mobile Applications Accessibility Impact on Business Activities,*** 2024, În: *Revista Economica*, 2024, nr.3(129), pp. 115-126, 0.55 c.a. ISSN 1810-9136 DOI: https://doi.org/10.53486/econ.2024.129.115. Categoria B. Available: https://irek.ase.md:443/xmlui/handle/123456789/3646.

3. Articles in the proceedings of conferences and other scientific events

3.2. in the works of scientific events included in other databases accepted by ANACEC

4. NASTAS, Vasile. ***Mobile application monetization.*** In: *Competitivitatea și inovarea în economia cunoașterii.* Ediția a 21-a, 27-28 septembrie 2019, Chișinău: CEP al ASEM, 2019, pp. 602-607. c.a. 0,44. ISBN 978-9975-75-968-7. Available: https://ibn.idsi.md/ro/vizualizare_articol/93310.

5. NASTAS, Vasile. ***Mobile applications with biometric authentication in business activities.*** In: *Simpozion Ştiinţific Internaţional al Tinerilor Cercetători; culegere de articole selective.* Ediția 17, 24-25 aprilie 2019, Chișinău: CEP al ASEM, 2019, pp. 245-250. c.a. 0,38. ISBN 978-9975-75-962-5. Available: https://ibn.idsi.md/sites/default/files/imag_file/245-250_4.pdf.

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7. NASTAS, Vasile, GHETMANCENCO, Svetlana. ***Methods of evaluation of the economic effect in mobile application development projects.*** In: *Development Through Research and Innovation-2020* [online]: The 1st International Scientific Conference: Online Conference for Reserachers, PhD and Post-Doctoral Students, August 28th, 2020. Conferaence Proceedings. Chișinău: CEP al, ASEM, 2021, pp. 17-27. c.a. 0,46. ISBN 978-9975-155-03-8. Available: https://ibn.idsi.md/ro/vizualizare_articol/140041.

8. NASTAS, Vasile. ***Impact of mobile applications over e-commerce.*** In: *Development Through Research and Innovation - 2021* [online]: The 2nd International Scientific Conference: Online Conference for Researchers, PhD and Post-Doctoral Students, August 27th, 2021, Chișinău: CEP al ASEM, 2021, pp. 23-30. c.a. 0,64. ISBN 978-9975-155-54-0. Available: https://ibn.idsi.md/ro/vizualizare_articol/144719.

9. NASTAS, Vasile. ***Benefits of mobile applications in the healthcare industry.*** In: *Proceedings of The 11th International Conference on Electronics, Communications and Computing ECCO-2021*, October 21-22, 2021. Chisinau: CEP al UTM, 2021, pp. 214-217. c.a. 0,2. ISBN 978-9975-45-776-7. Available: https://ibn.idsi.md/ro/vizualizare_articol/154929.

10. NASTAS, Vasile. ***Entertainment Mobile Applications 2022***, In: *International TELECONFERENCE of young researchers Creating the Society of Consciousness* (TELE-2022), 11th Edition of 18-19 March 2022, pp. 42-48. c.a. 0,12. e-ISBN 978-9975-155-54-0, DOI 10.5281/zenodo.5732859. Available: https://ibn.idsi.md/ro/vizualizare_articol/179241.

5. Other works and achievements specific to different scientific fields

11. BOLUN, Ion, GHETMANCENCO, Svetlana, NASTAS, Vasile. ***Efficiency indices of investment in IT projects with unequal lives***. In: *SworldJournal*, Issue 12, Part 1, 2022, pp. 16-34, c.a. 1,8. ISSN 2663-5712, DOI: 10.30888/2663-5712. Available: http://cris.utm.md/handle/5014/1823.

ADNOTARE

Nastas Vasile, Impactul aplicațiilor mobile asupra activităților de afaceri. Teză de doctor în informatică, specialitatea 122.02 Sisteme informatice, Chișinău, 2024

Structura tezei: introducere, trei capitole, concluzii finale și recomandări, bibliografie din 162 titluri, 8 anexe, 120 pagini de text de bază, 13 figuri, 9 tabele și 95 formule.

Numărul de publicații la tema tezei: rezultatele obținute sunt publicate în 11 lucrări științifice.

Cuvinte-cheie: proiecte de investiții, analiză comparativă, valoare actuală netă, indice de profitabilitate, rata internă de rentabilitate, beneficii soft, model.

Scopul lucrării constă în: cercetarea și dezvoltarea aspectelor teoretice și practice în perceperea impactului aplicațiilor mobile asupra activităților de afaceri; analiza și evaluarea impactului acestora asupra diferitelor tipuri de activități de afaceri prin modelarea matematică și simularea informatică.

Obiectivele cercetării constau în: cercetarea și extinderea bazei de cunoștințe privind conceptul de impact al aplicațiilor mobile în afaceri; identificarea beneficiilor aplicațiilor mobile în activitățile de afaceri; identificarea și modelarea costurilor de suportat de o organizație pentru o aplicație mobilă; identificarea și sistematizarea aspectelor legale privind distribuția aplicațiilor mobile; categorizarea și clasificarea aplicațiilor mobile pe domenii de activitate; identificarea tehnicilor și metodelor de estimare și măsurare a beneficiilor aplicațiilor mobile; identificarea metodelor de evaluare a rezonabilității investiției în aplicații mobile pentru activități de afaceri.

Noutatea și originalitatea științifică: caracteristicile cantitative și calitative ale beneficiilor de la implementarea aplicațiilor mobile pe categorii; identificarea și caracterizarea cantitativă și calitativă a beneficiilor utilizării aplicațiilor mobile pe categorii; recomandări privind dezvoltarea cadrului legislativ național referitor la implementarea aplicațiilor mobile relevante în afaceri; modele de evaluare a impactului aplicațiilor mobile asupra activităților de afaceri; recomandări privind dezvoltarea de aplicații mobile pentru diferite tipuri de organizații.

Problema științifică importantă soluționată în teză: sistematizarea, definirea, argumentarea și propunerea de soluții, inclusiv indici, tehnici, modele și probleme de optimizare, de evaluare a impactului aplicațiilor mobile în activitățile de afaceri și eficientizare a deciziilor privind dezvoltarea și implementarea unor asemenea aplicații.

Semnificația teoretică. Rezultatele obținute în lucrare constituie un suport revelator al conceptelor teoretice și metodologice în evaluarea TIC specifice aplicațiilor mobile, a ecosistemului aplicațiilor mobile și argumentarea impactului aplicațiilor mobile asupra activităților sustenabile de afaceri.

Valoarea aplicativă a lucrării. Rezultatele obținute prezintă un interes practic deosebit pentru mediul de afaceri privind utilizarea aplicații mobile. Acestea ajută la eficientizarea investițiilor în aplicațiile mobile și îmbunătățirea posibilelor rezultate.

Implementarea rezultatelor științifice. Rezultatele științifice obținute au fost implementate de cinci agenți economici, confirmând importanța temei de cercetare și valoarea aplicativă a rezultatelor obținute.

АННОТАЦИЯ

Настас Василе, Влияние мобильных приложений на бизнес-деятельность. Диссертация на соискание ученой степени доктора информатики, специальность 122.02 Информационные системы, Кишинев, 2024

Структура диссертации: введение, три главы, общие выводы и рекомендации, библиография из 162 наименований, 8 приложений, 120 страниц основного текста, 13 рисунков, 9 таблиц и 95 формул.

Публикации: полученные результаты были опубликованы в 11 научных работах.

Ключевые слова: инвестиционные проекты, сравнительный анализ, чистая приведенная стоимость, индекс рентабельности, внутренняя норма доходности, преимущества программного обеспечения, модель.

Цель работы состоит в: исследовании и разработке теоретических и практических аспектов восприятия влияния мобильных приложений на бизнес-деятельность; анализ и оценка их влияния на различные виды предпринимательской деятельности посредством математического моделирования и компьютерного симулирования.

Задачи исследования: исследование и расширение базы знаний по концепции влияния мобильных приложений на бизнес; выявление преимуществ мобильных приложений в деловой деятельности; выявление и моделирование затрат, которые должна нести организация за мобильное приложение; выявление и систематизация правовых аспектов распространения мобильных приложений; категоризация и классификация мобильных приложений по сферам деятельности; определение приемов и методов оценки и измерения преимуществ мобильных приложений; определение методов оценки разумности инвестиций в мобильные приложения для предпринимательской деятельности.

Оригинальность и научная новизна диссертации: количественные и качественные характеристики выгод от внедрения мобильных приложений по категориям; выявление и количественная и качественная характеристика преимуществ использования мобильных приложений по категориям; рекомендации по развитию национальной законодательной базы по внедрению соответствующих мобильных приложений в бизнес; модели оценки влияния мобильных приложений на деятельность бизнеса; рекомендации по разработке мобильных приложений для различных типов организаций.

Важная научная задача, решаемая в диссертации: систематизация, определение, аргументация и предложение решений, включая показатели, методы, модели и задачи оптимизации, для оценки влияния мобильных приложений на бизнес-деятельность и оптимизации решений, касающихся разработки и внедрения таких приложений.

Теоретическая значимость. полученные результаты представляют собой показательную поддержку теоретических и методологических концепций оценки ИКТ, специфичных для мобильных приложений, экосистемы мобильных приложений и обоснования влияния мобильных приложений на устойчивую бизнес-деятельность.

Прикладная ценность: полученные результаты представляют особый практический интерес для бизнес-среды, связанной с использованием мобильных приложений. Они помогают оптимизировать инвестиции в мобильные приложения и улучшить возможные результаты.

Внедрение научных результатов: полученные научные результаты были внедрены пятью экономическими агентами, подтвердив актуальность темы исследования и прикладную ценность полученных результатов.

ANNOTATION

Nastas Vasile, The impact of mobile applications on business activities. PhD thesis in computer science, specialty 122.02 Information Systems, Chișinău, 2024

Thesis structure: introduction, three chapters, final conclusions and recommendations, bibliography of 162 titles, 8 annexes, 120 pages of main text, 13 figures, 9 tables, and 95 formulas.

Number of publications on the topic of the thesis. The main research results of this thesis were published in 11 papers.

Keywords: investment projects, comparative analysis, net present value, profitability index, internal rate of return, software benefits, model.

The purpose of the work: research and development of theoretical and practical aspects in perceiving the impact of mobile applications on business activities; analyzing and evaluating their impact on different types of business activities through mathematical modeling and computer simulation.

The objectives of the research are: researching and expanding the knowledge base on the concept of business impact of mobile applications; identifying the benefits of mobile applications in business activities; identifying and modeling the costs to be supported by an organization for a mobile application; identification and systematization of legal aspects regarding the distribution of mobile applications; categorization and classification of mobile applications by fields of activity; identifying techniques and methods for estimating and measuring the benefits of mobile applications; identifying methods for assessing the reasonability of investment in mobile applications for business activities.

The scientific novelty and originality resides in: quantitative and qualitative characteristics of benefits from the implementation of mobile applications by category; identification and quantitative and qualitative characterization of the benefits of using mobile applications by category; recommendations regarding the development of the national legislative framework regarding the implementation of relevant mobile applications in business; models for assessing the impact of mobile applications on business activities; recommendations on developing mobile applications for different types of organizations.

The important scientific problem solved in the thesis: the systematization, definition, argumentation and proposal of solutions, including indices, techniques, models and optimization problems, to evaluate the impact of mobile applications in business activities and to streamline decisions regarding the development and implementation of such applications.

Theoretical significance. The results obtained in the thesis constitute a revealing support of the theoretical and methodological concepts in the assessment of ICT specific to mobile applications, of the ecosystem of mobile applications and the argumentation of the impact of mobile applications on sustainable business activities.

The applicative value of the thesis. The obtained results are of particular practical interest for the business environment regarding the use of mobile applications. They help streamline your mobile app investment and improve your potential results.

Implementation of scientific results. The obtained scientific results were implemented by five economic agents, confirming the importance of the research theme and the applied value of the obtained results.

NASTAS VASILE

IMPACTUL APLICAȚIILOR MOBILE ASUPRA ACTIVITĂȚILOR DE AFACERI

Specialitatea 122.02 Sisteme informatice

Rezumatul tezei de doctor în informatică

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