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MEASURING THE IMPACT OF MOBILE APPLICATIONS

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Abstract. Although mobile devices have widespread popularity, allowing, for example, companies to innovate, streamline operations, and maintain a competitive advantage in a rapidly evolving market, the economic impact of using mobile applications (apps) is less researched. In an attempt to improve the state of affairs in the field, this paper provides a classification (based on business domains) and defines models for calculating the costs of developing and using mobile apps in various situations. To evaluate the economic impact of mobile apps, the opportunity of use is argued and the mathematical expressions for calculating the quantitative indices, Net Present Value, Profitability and Internal Rate of Return, eventually in conjunction with the Equivalent Annual Value method, are determined for 12 specific cases of development and use of mobile apps. Also, multiple qualitative indices for measuring the impact of mobile apps are succinctly characterized and systematized. In confirmation of the significant economic and social impact of mobile apps, three implementations of them in various fields are described.

Keywords: *classification, mobile application costs, mobile application system, qualitative indices, quantitative indices, use cases.*

Rezumat. Deși dispozitivele mobile se bucură de o largă popularitate, permițând, de exemplu, companiilor să inoveze, să eficientizeze operațiunile și să mențină un avantaj competitiv pe o piață în evoluție rapidă, impactul economic al utilizării aplicațiilor mobile este mai puțin cercetat. În încercarea de a îmbunătăți starea de lucruri în domeniu, această lucrare oferă o clasificare (pe baza domeniilor de afaceri) și definește modele de calculare a costurilor de dezvoltare și utilizare a aplicațiilor mobile în diferite situații. Pentru evaluarea impactului economic al aplicațiilor mobile, se argumentează oportunitatea utilizării și se determină expresiile matematice pentru calcularea indicilor cantitativi, Valoarea Actuală Netă, Profitabilitatea și Rata Internă de Rentabilitate, eventual împreună cu metoda Valorii Anuale Echivalente, pentru 12 cazuri specifice de dezvoltare și utilizare a aplicațiilor mobile. De asemenea, mai mulți indici calitativi pentru măsurarea impactului aplicațiilor mobile sunt succint caracterizați și sistematizați. Pentru a confirma impactul economic și social semnificativ al aplicațiilor mobile, sunt descrise trei implementări ale acestora în diverse domenii.

Cuvinte cheie: *clasificare, costuri cu aplicațiile mobile, sistem de aplicații mobile, indici calitativi, indici cantitativi, cazuri de utilizare.*

1. Introduction

Today's business environment is complex and competitive. Organizations, day by day, are increasingly forced to adjust their affairs and be more agile. 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; therefore, they strongly rely on Information and Communication Technologies (ICT) support. Nowadays, there are over 5.44 billion ICT users out of 8.17 billion global population [1]. Combining business and technology, companies grow faster and plan more effective business strategies. Among these strategies and opportunities an important role belongs to mobile applications (apps), the use of which grows in a fast linear progression [2]. These apps enable businesses to innovate, streamline operations, and maintain a competitive edge in a rapidly evolving market.

One of the most tangible values of mobile apps is their ability to enhance customer engagement. According to eMarketer [3], "in 2023, the average U.S. adult spent over four hours per day on mobile devices, with nearly 90% of that time spent on apps". An Adobe survey [4] revealed that "companies utilizing mobile apps for internal operations reported a 44% increase in employees' productivity". According to IBM [5], "90% of the world's data has been created in the last two years alone, with much of it generated by mobile devices".

Statistics predicts [6] that the number of smartphone users worldwide is expected to reach 7.33 billion by 2025, providing businesses with unprecedented access to global consumers. Oberlo reported [7] that "mobile commerce is projected to account for 63% of all e-commerce sales by 2028". A study by Business Insider [8] "found that 78% of mobile searches for local business information result in a purchase". According to Statista Market Insights, mobile POS payments apps have revolutionized the financial services industry; such payments projected to surpass US$12.5 trillion globally in 2025 [9].

However, the development of mobile apps involves expenses, often significant. Since financial resources, and not only, are limited, it is important to make such expenses more efficient. But for this, it is required to estimate the impact of mobile apps on various activities, which in turn involves rigorous measurements of some respective indices. Despite their significance, measuring the impact of mobile applications present a unique set of challenges, unlike traditional ICT projects where outcomes can be directly observed or quantified, the benefits of mobile apps often manifest in intangible ways. At the same time, there are still no well-defined rigorous methods for this purpose.

Considering the importance and widespread use of mobile apps, the main objective of this paper is to explore reasonable methodologies for measuring the impact of mobile apps. The focus will be on identifying key metrics, selecting appropriate approaches, and addressing common challenges associated with impact measurement.

2. Materials, methodology and methods

2.1. Methodologies used to evaluate the mobile applications impact

The subject regarding the impact of mobile apps was explored and researched by P. Karami [10], I.M. Tactuk, N. Munaiah, and A. Meneely [11], A. Holden [12], H. Heflin, J. Shewmaker, and J. Nguyen [13], K. Hahn [14], A.R. Altaleb [15], etc. Most researchers address qualitative impact and conduct analyses through survey method [13], interview method [14,15] or scoring method [16].

At the same time, mostly all mentioned authors and others touch the topic of mobile apps by solving a specific problem. They took a targeted use case related to a mobile app and how it can solve a business issue. But there is no in-depth study described on the impact of mobile apps themselves. Parts of research, such as measurable quantitative impact that could help businesses improve their activities usually are missing. They do not generalize a global formulation of the problem and propose generic solutions for measuring the impact. Here comes the biggest challenge, most organizations want to enter this environment and achieve new results, but there is poor research and it is not clearly understood what impact mobile applications specifically will bring to businesses.

Measuring the impact of a mobile app can be complex and multi-dimensional, due to the intangible nature of many benefits that it brings, such as enhanced customer experience or improved decision-making capabilities. The specific criteria or indices used depend on the context and goals of what is being measured. These are needed for every business to understand the value of their investment and present informative reports to investors or stakeholders. To determine what indices to choose for evaluating the impact of mobile application on a specific business affair, it is needed to determine, first of all, what type of impact is expected to achieve.

2.2. Mobile applications classification based on business domains

The most popular mobile stores worldwide are Google Play Store and Apple App Store. It can be observed that there are a lot of mobile app categories on each store, namely:

1. Google Play Store has 3805891 applications available for download [17], where:
   a. 96.98% applications are for free (3686297 apps).
   b. 3.02% applications are paid (114929 apps).
2. Apple App Store has 1807268 applications available for download [18], where:
   a. 87.89% applications are for free (1588326 apps).
   b. 12.11% applications are paid (218942 apps).

The number of available mobile apps on each store depends on many factors as: selected countries, selected category, review process that approves or rejects depending on compliance, and other local or store restrictions. The mobile stores specify a lot of categories in order to define what type of application is more appropriate to one of their categories, what policies and regulations (depending on the countries selected for distribution) they should apply and to let the auditory or users that download the app to understand what type of application they are downloading. On both, Google Play Store and Apple App Store, there are a lot of categories and classifications. Putting aside the mobile store app categories and business domains classifications, the mobile applications under different business activities groups could be classified into the following categories:

1. E-commerce and Retail Applications.
2. Banking and Finance Applications.
3. Healthcare and Fitness Applications.
4. Entertainment and Media Applications.
5. Educational and Learning Applications.
6. Productivity and Business Management Applications.
7. Travel and Hospitality Applications.
8. Social Networking and Communication Applications.
9. Real Estate and Property Management Applications.

10. Food Delivery and Restaurant Applications.
11. Utilities and others.

The main idea is not to target the mobile application type itself, but to go over the main purpose and scope of the application for the end users.

2.3. General indices for measuring the impact

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.

Quantitative indices

Mobile apps are IT applications. A decision of investment in an IT project (i-project) is usually made based on efficiency criteria/indices. For the assessment of economic efficiency of investment projects, in various sources is recommended to use such quantitative indices as: profit, profit rate [19], payback period (PP), net present value (NPV) [20], profitability index (PI) [19], internal rate of return (IRR) [19,20], return on investment (ROI) [19,21], adjusted expenditure [21], total costs of ownership [22] and so on.

The known theoretical results do not give an unambiguous answer on preferences of using, in concrete situations, the indices for the estimation of efficiency of investment in i-projects.

The most synthetic index of the efficiency of economic activity of an economic agent as a whole is considered the profit rate [19]. In methodological recommendations [20], the basic indices for estimating the economic efficiency of investment projects are: net value, NPV, IRR, ROI, PP and indices that characterize the financial state of the enterprise participating in the project. The World Bank's financial criteria for choosing an investment project are: PP, NPV, discount rate, IRR, and PI [23].

The comparative analysis carried out in [24,25] of the 16 indices for i-projects, the income from the implementation of which can be estimated with reasonable efforts, led to the reduction of the number of core indices from 16 to 3, namely: NPV, IRR and PI, eventually in conjunction with the equivalent annual value (EAV) method. It is proved that for such i-projects the solution, obtained by using any of the other 13 indices, coincides with the solution, obtained by using one or more of the three indices mentioned above. At the same time the NPV, IRR and PI indices form a Pareto set. Thus, not taking any of them into account can lead to unsuccessful decisions.

A key role in calculating the **Net Present Value** is played by the choice of the discount rate d, which must consider the significance of risks and the decrease in the value of money in the future. Let I_{it} are investments and CF_{it} are cash flows in year t related to the mobile application i. Then NPV index for the mobile app i, i.e. NPV_i, is determined as [21]:

$$NPV_i = \sum_{t=1}^{L_i} \frac{CF_{it}}{(1+d)^t} = \sum_{t=1}^{L_i} \frac{P_{it} + AA_{it} - I_{it}}{(1+d)^t}, i = \overline{1,n}, \quad (1)$$

where: n is the total number of considered mobile apps, I_i – total investment with the project, L_i – the duration of the project, P_{it} – the profit and AA_{it} – the amortization in year t with refer to mobile app i. For the NPV calculation, the rate d usually used is equal to the WACC (weighted average cost of capital) value [26] or the historical average returns of a similar project.

Usually, contributions from a product appear only after all the investments in it have been appropriated. If the investment takes more than one year, then the expression (1) can be presented in the form

$$\mathrm{NPV}_i = -\sum_{t=1}^{\tau_i} \frac{I_{it}}{(1+d)^t} + \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} = \sum_{t=\tau_i+1}^{L_i} \frac{\mathrm{CF}_{it}}{(1+d)^t} - I_i\,, i = \overline{1,n}, \tag{2}$$

where: $L_i = \tau_i + D_i$, τ_i is the duration of the acquisition of investments (own development) and D_i is the duration of the use of mobile application *i*.

The **Internal Rate of Return** [21] of a project shows the rate at which investments in the project pay off, i.e. the present value of investments is zero. So, taking into account (2), the IRR for mobile application *i*, i.e. IRR_i, is determined by solving the equation [21]:

$$-\sum_{t=1}^{\tau_i} \frac{I_{it}}{(1+\mathrm{IRR})^t} + \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+\mathrm{IRR})^t} = \sum_{t=\tau_i+1}^{L_i} \frac{\mathrm{CF}_{it}}{(1+\mathrm{IRR})^t} - I_i = 0, i = \overline{1,n}. \tag{3}$$

The **Profitability Index** for the mobile application *i*, i.e. PI_i, is calculated by dividing the present value of future cash flows generated by the mobile application by the initial investment required [24]:

$$\mathrm{PI}_i = 1 + \frac{\mathrm{NPV}_i}{I_i}, i = \overline{1,n}. \tag{4}$$

The **Equivalent Annual Value method** is used for the appropriate comparison of projects with different lifetimes [27]. 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. 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

$$\mathrm{EAXX} = \mathrm{CRF} \times \mathrm{XX}, \tag{5}$$

where:

$$\mathrm{CRF} = \left[\sum_{t=1}^{D} \frac{1}{(1+d)^t}\right]^{-1} = \frac{d(1+d)^D}{(1+d)^D - 1}. \tag{6}$$

So, one has:

$$\mathrm{EANPV} = \mathrm{CRF} \times \mathrm{NPV}; \tag{7}$$

$$\mathrm{EAPI} = \mathrm{CRF} \times \mathrm{PI}. \tag{8}$$

Qualitative indices [28]

Qualitative indices for mobile apps 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 group of such indices are Acquisition, Engagement, Monetization and Retention.

The **Acquisition indices group** is mainly composed from user acquisition, traffic acquisition and user acquisition cohorts. *User acquisition* refers to the process of tracking how new users are brought to a mobile app. The most common user acquisition indices are: New users, Session duration, Screen session, and Conversion.

Traffic acquisition focuses on understanding how users arrive at a mobile app and the quality of traffic driven from various sources. Key components of traffic acquisition include Channels, Search traffic, Direct traffic, Social traffic, and Referral traffic.

User acquisition cohorts refer to a specific feature that groups users based on common characteristics, particularly when they acquired or started using a mobile app. Key elements of user acquisition cohorts in Google Analytics include Cohort definition, Cohort metrics, Behavioral patterns, and Comparing acquisition channels.

The **Engagement indices group** is mainly composed from events and screens. *Engagement events* are specific actions or interactions that users take within a mobile app, providing deeper insights into user behavior beyond basic metrics like screen views or session duration. Key aspects of engagement events include Event categories, Event actions, Tracking engagement metrics, and Custom event tracking.

Screens refers to a report that provides insights into how users navigate and interact with the various screens within a mobile app. Key elements of the "Pages and Screens" report include: Screenviews, Average time on screen, Screen pathing, User interaction on screens, and Conversion tracking.

The **Monetization indices group** is mainly composed from Purchase journey, Checkout journey and In-app purchase. The *Purchase journey* refers to the path a user takes from their initial interaction with a website or app to the final step of completing a purchase. By understanding how users move through each stage of this journey, businesses can tailor their strategies to meet customer needs at every point, from acquisition to checkout and beyond.

The *Checkout journey* refers to the steps a user takes once he decides to make a purchase and proceed to the checkout process. Understanding the checkout journey enables businesses to identify bottlenecks, reduce misunderstandings, and enhance the user experience, ultimately leading to higher conversion rates and more completed purchases.

By tracking *In-app purchase* (IAP) businesses can gain valuable insights into user behavior, optimize their monetization strategies, and enhance the overall performance of their mobile app. This data enables informed decision-making that drives higher revenue and improves user satisfaction with IAP.

The **Retention indices** group refers to the tracking and measurement of how frequently users return to a website or mobile app over time. Key aspects of retention tracking include User retention rates, Cohort analysis for retention, Active users, Churn rate, and Retention by device or platform.

3. Results and discussions

From many points of view, mobile apps can suit different business and no business activities in many aspects, but besides need and opportunities, it is required to understand the costs of buying or developing from scratch such mobile apps. These costs are taken into account by NPV, IRR, and PI indices.

3.1. Evaluate development cost of a mobile application

Developing a mobile app is nothing different than developing any other type of software solution, basically all of them share mostly the same Software Development Life Cycle (SDLC), just each so called target platform (web, desktop, mobile) has its own specifics or narrow. Taking into consideration SDLC and understanding that a person cannot cover complete all or several roles according to its effect over the performance, most economic

agents prefer Agile methodologies for delivering software solutions over traditional ones as Waterfall, due to many reasons regarding delivery time, costs and change requests from the product owner [29]. In order to handle a single mobile app with a set of features based on Agile framework, it is required an agile team that at least would consist of a group of employees (by categories):

1. Software engineers that will deal with mobile development.
2. Designers that will deal with the user experience and user interface.
3. Quality assurance engineers that will deal with testing phase of the application.
4. Managers that will handle the team, be responsible for the requirement and deliveries.

From business and costs point of view the agile methodology, in order to calculate the costs for delivering a mobile app, will require the following characteristics:

H_k- total number of hours spent by employees of category *k*, $k = \overline{1,4}$;

R_k- rate per hour for an employee of category *k*, $k = \overline{1,4}$;

M - miscellaneous costs, such as licensing, 3rd party services, etc.

The costs of a mobile app i will be marked as C_i, $i = \overline{1,n}$, where *n* is the number of mobile apps. Considering the costs with employees, the mobile app *i* costs are determined as

$$C_i = \sum_{k=1}^{4} H_{ki} R_k + M_i, i = \overline{1,n}, \quad (9)$$

where: H_{ki} is the number of hours spent by employees of category *k* to develop the mobile app *i*.

As any other software product, besides the first phase of development and delivery, it also could have new development phases and maintenance. Here comes the specific software development that was discussed above, people and organizations in average keep their mobile devices for a period between 2-4 years, afterwards replace them with newer ones because of better hardware capabilities, battery life and support of new version of mobile operating systems (OS). This replacement can be observed with fast adoption of updates for OS for iOS [30] and Android [31] devices on a global level. Due to many technical and legal reasons, with each OS update over the mobile device, come a lot of changes like new features for users and developers to implement, deprecated features in previous OS versions, new security updates and restrictions by the OS, etc.

Going over the mentioned adoption and changes, will be considered the total required investments as well for maintaining a mobile app that will be marked E. The mobile apps investments, during maintenance period for E consist from minor development and update distribution. These investments are mostly required because people are used to do regular mobile OS updates [30,31] and mobile app market stores might require applying several changes within the mobile app, otherwise it can be blocked or removed completely from their marketplace. Most private organization offer different types of maintenance packages, like on-demand, monthly, yearly or specific number of hours. These costs are covered separately and on beneficiary wish. In other words, if the beneficiary will need maintenance, then it will have to support these costs. These are several conclusions, recommendations regarding going for or no maintenance:

1. If the beneficiary does not have in mind to change the mobile devices and use it only internally for a long period of time (at least 5-7 years), then he doesn't need the maintenance part.

2. The maintenance part for mobile apps consists mainly in updates within the code and submitting to the distribution layer new mobile apps versions. Mobile OS updates are coming around every year and their major transition takes around another year.

3. The maintenance costs are evaluated around 20% of the initial core development of the mobile apps [32].

4. If the development phase of a mobile app passes a certain period of time and it's near the release of new versions of OS, then the beneficiary should take the maintenance part in order to continue further with mobile stores permissions.

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 app is designed only for public use and covering both platforms. These use cases are the following:

- mobile apps for internal use only (Cases):
  a) develop and use only an Android or an iOS mobile app;
  b) develop and use both an Android and an iOS mobile app;
- mobile apps for external use (Cases):
  c) develop and distribute only an Android or an iOS mobile app;
  d) develop and distribute both an Android and an iOS mobile app;
- mobile apps 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.

Cases (a)-(f) look similar, but in real life the costs are different. Each of Cases (a)-(f) will be analyzed separately.

Case a. *Develop and internal use only an Android or an iOS mobile app*

For internal use it is required to develop and, also, to cover the maintenance costs of a mobile application *i*. The maintenance costs, considered equal with an Android and with an iOS mobile app and marked E_i, is around 20% of the initial development [32]. So, taking into account (9), one has

$$E_i = 0.2\sum_{k=1}^{4} H_{ki}R_k\,, i = \overline{1,n}. \tag{10}$$

Thus, the total costs for a beneficiary with the development (see (9)) and maintenance (see (10)) of a mobile app *i* for internal use is determined as

$$C_i + E_i = \sum_{k=1}^{4} H_{ki}R_k + M_i + 0.2\sum_{k=1}^{4} H_{ki}R_k = 1.2\sum_{k=1}^{4} H_{ki}R_k + M_i, i = \overline{1,n}. \tag{11}$$

Case b. *Develop and internal use both an Android and an iOS mobile app*

To develop, maintain and internal using both an Android and an iOS mobile app, it is needed doubling costs for one of them. Taking into account (3), the total costs for a beneficiary with the development and maintenance of an Android and an iOS mobile app *i* for internal use is determined as

$$2(C_i + E_i) = 2.4\sum_{k=1}^{4} H_{ki}R_k + 2M_i, i = \overline{1,n}. \tag{12}$$

Case c. *Develop and distribute only an Android or an iOS mobile app*

In this case will be supported the same costs for development and maintenance determined according to formula (11) as in case (a), the only difference is that the Android distribution to mass public will require to pay many mobile store accounts, when with regard to the iOS distribution to mass public will require to pay only one mobile store account. Distributing an Android mobile app can be done only by manually sharing the .apk file or other free distribution service like Firebase App Distribution [33]. If to compare the distribution of an Android app with the one of an iOS app, we will have a lot more options where we can distribute it, not only for Europe or United States users, but as well for those which live in the Asia. Here is a list of places and prices that apply for publishing on their stores [28]:

1. Google Play Store (25 USD one-time payment).
2. Amazon AppStore (free distribution).
3. Samsung Galaxy Store (free distribution).
4. Huawei AppGallery (free distribution).
5. F-droid (free distribution).
6. Oppo App Market (free distribution).
7. Xiaomi Mi Store (free distribution), etc.

Most of Android mobile app stores have free distribution option to mass public or at least require a small and symbolic fee in order to use their platform. So, the total costs for a developer to develop, maintain and distribute an Android mobile application *i* (Case c.1), based on (11), is determined as:

$$C_i + E_i + \sum_{s=1}^{S} C_{si} = 1.2 \sum_{k=1}^{4} H_{ki} R_k + \sum_{s=1}^{S} C_{si} + M_i, i = \overline{1,n}, \quad (13)$$

where: $C_{si} \geq 0$ are Android mobile app store *s* costs for the mobile app *i,* and $S \geqslant 1$ is the number of Android mobile app stores to be supported.

At the moment, in order to distribute an iOS mobile app is necessary to have an Apple Developer Account due to OS restrictions and certificates released by Apple for their devices, so additionally to this will be added the costs of the developer platform. Distribution policy and restrictions enforce to have additional 99 USD per year costs [34]. So, the total costs for a developer to develop, maintain and distribute an iOS mobile app *i* (Case c.2), based on (11), is determined as

$$C_i + E_i + C_{\mathrm{O}i} = 1.2 \sum_{k=1}^{4} H_{ki} R_k + C_{\mathrm{O}i} + M_i, i = \overline{1,n}, \quad (14)$$

where: $C_{\mathrm{O}i} \geq 0$ are iOS mobile app store costs for the mobile app *i*.

At the same time, when sailing a product its price is equal to costs with it multiplied by (1 + established profit rate). Let established profit rate be marked as PR. Usually, $d \leqslant \mathrm{PR} \leqslant 0.2$.

So, for a purchaser, the price I_i (investment) for an Android or an iOS mobile app *i* (Case c.3), taking into account (11), is determined as:

$$I_i = (C_i + E_i)(1 + \mathrm{PR}) = (1 + \mathrm{PR}) \left(1.2 \sum_{k=1}^{4} H_{ki} R_k + M_i \right), i = \overline{1,n}. \quad (15)$$

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

For a developer (Case d.1), to develop, maintain and distribute both an Android and an iOS mobile app needs total costs determined by summing the costs according to formulas (13) and (14), that is:

$$C_i + E_i + \sum_{s=1}^{S} C_{si} + C_i + E_i + C_{Oi} = 2.4 \sum_{k=1}^{4} H_{ki} R_k + \sum_{s=1}^{S} C_{si} + C_{Oi} + 2M_i, i = \overline{1,n}. \quad (16)$$

Evidently, for a purchaser, the price I_i (investment) for an Android or an iOS mobile app *i* (Case d.2) is determined according to (15).

Case e. *Develop, internal use and distribute only an Android or an iOS mobile application*

In this case, the costs with a mobile app *i* supported by a developer are the same as in Cases c.1 and c.2, that is they are determined according to (13), for an Android mobile app (Case e.1), and - according to (14), for an iOS mobile app (Case e.2). Of course, in both cases, the respective cash flows, including the estimated profit, are different being higher than in Cases c.1 and c.2.

At the same time, for a purchaser (Case e.3) the price for a mobile app *i* is the same as in Case c.3, i.e. it is determined according to (15).

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

In a similar mode, the costs with a mobile app *i* supported by a developer (Case f.1) are the same as in Case d.1, that is they are determined according to (16). Of course, the respective cash flows, including the estimated profit, are different being higher than in Cases c.1, c.2, d.1, e.1, and e.2.

Also, as in Cases d.2 and e.3, for a purchaser (Case f.2) the price for a mobile app *i* is the same as in Case c.3, i.e. it is determined according to (15).

Resuming on Cases (a)-(f), for a developer one can conclude that by total costs with a mobile application the relations among the cases are

$$\text{(a)} \leqslant \text{c.2} = \text{e.2} \leqslant \text{c.1} = \text{e.1} \leqslant \text{(b)} \leqslant \text{d.1} = \text{f.1}, \quad (17)$$

and by total profit on a mobile application the relations usually are:

$$\text{f.1} \geqslant \text{d.1} \geqslant \text{e.1} \geqslant \text{c.1} \geqslant \text{e.2} \geqslant \text{c.2} \geqslant \text{(a)} \geqslant \text{(b)}. \quad (18)$$

In its turn, for a purchaser the price for a mobile application *i* is the same in all cases, i.e. Cases c.3, d.2, e.3, and f.2, and is determined according to (15).

Cases (a)-(f) show how costs can vary depending on the requirement if it is of internal, of external or both of internal and external usage. If to take a look over device adoptions statistics analyzed by Andrew Buck on MobiLoud [35], one has the device adoption by zone shown in Table 1.

Table 1

Mobile device adoptions statistics [35]

Zone\Platform	iOS	Android	Other
North America	58%	41%	1%
Europe	33%	66%	1%
Asia	20%	79%	1%
Africa	13%	85%	2%
South America	16%	84%	0%

From the current values, one can observe and conclude that Case (b) would be relevant only for North America and Europe zones and there is a big chance that it won't be reasonable to invest because iOS mobile devices produced by Apple have a pricing model higher than any other Android mobile device produced by other companies.

After determining the development costs or required investment for a mobile app, it is important to understand and choose right quantitative indices for measuring their impact.

3.2. Quantitative indices for measuring the impact by use cases

In possible impact of the use of mobile apps, measured by NPV, IRR, and PI indices, each of Cases (a)-(f), described in Section 3.1, will be 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. To scenario {j = 1, n = 1}, for a developer correspond Cases (a), c.1, c.2, e.1, and e.2 and for a purchaser - Cases c.3, d.2, e.3, and f.2. At the same time, to scenario {j = 1, n = 2}, for a developer correspond Cases (b), d.1, and f.1, and for a purchaser - there are no such cases. Knowing the expressions of quantitative indices for these scenarios, it is easy to determine the corresponding expressions for other scenarios, too.

In all examined below cases, it will be considered the mobile app i and the C_i cost is determined according to (9).

Net Present Value by use cases

Taking into account the costs for each of Cases (a)-(f), the NPV is determined according to formula (2), where:

- for a purchaser (Cases c.3, d.2, e.3, and f.2) occurs $\tau_i = 0$. Thus, one has:

$$\mathrm{NPV}_i = \sum_{t=1}^{D_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - I_i, \tag{19}$$

where: I_i is determined according to (15);

- for a developer in Case (a), occurs $I_i = C_i$. So, is obtained

$$\mathrm{NPV}_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - C_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - \sum_{k=1}^{4} H_{ki} R_k - M_i; \tag{20}$$

- for a developer in Cases c.1 and e.1, occurs $I_i = C_i + \sum_{s=1}^{S} C_{si}$. Thus, is obtained

$$\begin{aligned} \mathrm{NPV}_i = & \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - C_i - \sum_{s=1}^{S} C_{si} = \\ & = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - \sum_{k=1}^{4} H_{ki} R_k - \sum_{s=1}^{S} C_{si} - M_i; \end{aligned} \tag{21}$$

- for a developer in Cases c.2 and e.2, occurs $I_i = C_i + C_{\mathrm{O}i}$. So, finally, is obtained

$$\mathrm{NPV}_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - C_i - C_{\mathrm{O}i} == \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - \sum_{k=1}^{4} H_{ki} R_k - C_{\mathrm{O}i} - M_i; \tag{22}$$

- for a developer in Case (b), occurs $I_i = 2C_i$. Thus, is obtained

$$\mathrm{NPV}_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - 2C_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \mathrm{AA}_{it}}{(1+d)^t} - 2\left(\sum_{k=1}^{4} H_{ki} R_k - M_i\right); \tag{23}$$

- for a developer in Cases d.1 and f.1, occurs $I_i = 2C_i + C_{Oi} + \sum_{s=1}^{S} C_{si}$. So, is obtained

$$\begin{aligned} \text{NPV}_i = &\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+d)^t} - 2C_i - C_{Oi} - \sum_{s=1}^{S} C_{si} = \\ &= \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+d)^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right) - C_{Oi} - \sum_{s=1}^{S} C_{si}. \end{aligned} \tag{24}$$

Internal Rate of Return by use cases

In general case, the value of the IRR for mobile app *i* is determined by solving the equation (3). In a similar mode, by use cases, taking into account relationships (3) and (19)-(24), the value of IRR for mobile app *i* is determined:

- for a purchaser (Cases c.3, d.2, e.3, and f.2), because $\tau_i = 0$, by solving the equation

$$\sum_{t=1}^{D_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - I_i = 0, \tag{25}$$

where I_i is determined according to (15);

- for a developer in Case (a), because $I_i = C_i$, by solving the equation

$$\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - C_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - \sum_{k=1}^{4} H_{ki}R_k - M_i = 0; \tag{26}$$

- for a developer in Cases c.1 and e.1, because $I_i = C_i + \sum_{s=1}^{S} C_{si}$, by solving the equation

$$\begin{aligned} &\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - C_i - \sum_{s=1}^{S} C_{si} = \\ &= \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - \sum_{k=1}^{4} H_{ki}R_k - \sum_{s=1}^{S} C_{si} - M_i = 0; \end{aligned} \tag{27}$$

- for a developer in Cases c.2 and e.2, because $I_i = C_i + C_{Oi}$, by solving the equation

$$\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - C_i - C_{Oi} = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - \sum_{k=1}^{4} H_{ki}R_k - C_{Oi} - M_i = 0; \tag{28}$$

- for a developer in Case (b), because $I_i = 2C_i$, by solving the equation

$$\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - 2C_i = \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right) = 0; \tag{29}$$

- for a developer in Cases d.1 and f.1, because $I_i = 2C_i + C_{Oi} + \sum_{s=1}^{S} C_{si}$, by solving the equation

$$\begin{aligned} &\sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - 2C_i - C_{Oi} - \sum_{s=1}^{S} C_{si} = \\ &= \sum_{t=\tau_i+1}^{L_i} \frac{P_{it} + \text{AA}_{it}}{(1+\text{IRR})^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right) - C_{Oi} - \sum_{s=1}^{S} C_{si} = 0. \end{aligned} \tag{30}$$

Profitability Index by use cases

Taking into account the costs for each of Cases (a)-(f), the PI is determined according to formula (4), where:

- for a purchaser (Cases c.3, d.2, e.3, and f.2), occurs $\tau_i = 0$. Thus, one has

$$\mathrm{PI}_i = \frac{1}{I_i}\sum_{t=1}^{D_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t}, \tag{31}$$

where I_i is determined according to (15);

- for a developer in Case (a), occurs $I_i = C_i$. So, is obtained

$$\mathrm{PI}_i = \sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t}\Bigg/\left(\sum_{k=1}^{4}H_{ki}R_k - M_i\right); \tag{32}$$

- for a developer in Cases c.1 and e.1, occurs $I_i = C_i + \sum_{s=1}^{S} C_{si}$. Thus, one has

$$\mathrm{PI}_i = \sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t}\Bigg/\left(\sum_{k=1}^{4}H_{ki}R_k - \sum_{s=1}^{S}C_{si} - M_i\right); \tag{33}$$

- for a developer in Cases c.2 and e.2, occurs $I_i = C_i + C_{\mathrm{O}i}$. So, is obtained

$$\mathrm{PI}_i = \sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t}\Bigg/\left(\sum_{k=1}^{4}H_{ki}R_k - C_{Oi} - M_i\right); \tag{34}$$

- for a developer in Case (b), occurs $I_i = 2C_i$. Thus, one has

$$\mathrm{PI}_i = \sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t}\Bigg/2\left(\sum_{k=1}^{4}H_{ki}R_k - M_i\right); \tag{35}$$

- for a developer in Cases d.1 and f.1, occurs $I_i = 2C_i + C_{\mathrm{O}i} + \sum_{s=1}^{S} C_{si}$. So, is obtained

$$\mathrm{PI}_i = \sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t}\Bigg/\left[2\left(\sum_{k=1}^{4}H_{ki}R_k - M_i\right) - C_{\mathrm{O}i} - \sum_{s=1}^{S}C_{si}\right]. \tag{36}$$

Equivalent Annual Net Present Value by use cases

With refer to the EANPV, based on formulas (6) and (7) and taking into account the formulas for NPV in each of Cases (a)-(f), one has

$$\begin{aligned}\mathrm{EANPV}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left[\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t} - \sum_{t=1}^{\tau_i}\frac{I_{it}}{(1+d)^t}\right] = \\ = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left[\sum_{t=\tau_i+1}^{L_i}\frac{\mathrm{CF}_{it}}{(1+d)^t} - I_i\right],\end{aligned} \tag{37}$$

where:

- for a purchaser (Cases c.3, d.2, e.3, and f.2), occurs $\tau_i = 0$. Thus, one has

$$\mathrm{EANPV}_i = \frac{d(1+d)^{D_i}}{(1+d)^{D_i}-1}\left[\sum_{t=1}^{D_i}\frac{P_{it}+\mathrm{AA}_{it}}{(1+d)^t} - I_i\right], \tag{38}$$

where I_i is determined according to (2.7);

- for a developer in Case (a), occurs $I_i = C_i$. So, is obtained

$$\text{EANPV}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left[\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t} - \sum_{k=1}^{4} H_{ki}R_k - M_i\right]; \quad (39)$$

- for a developer in Cases c.1 and e.1, occurs $I_i = C_i + \sum_{s=1}^{S} C_{si}$. Thus, is obtained

$$\text{EANPV}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left[\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t} - \sum_{k=1}^{4} H_{ki}R_k - \sum_{s=1}^{S} C_{si} - M_i\right]; \quad (40)$$

- for a developer in Cases c.2 and e.2, occurs $I_i = C_i + C_{\text{O}i}$. So, is obtained

$$\text{EANPV}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left[\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t} - \sum_{k=1}^{4} H_{ki}R_k - C_{\text{O}i} - M_i\right]; \quad (41)$$

- for a developer in Case (b), occurs $I_i = 2C_i$. Thus, is obtained

$$\text{EANPV}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left[\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right)\right]; \quad (42)$$

- for a developer in Cases d.1 and f.1, occurs $I_i = 2C_i + C_{\text{O}i} + \sum_{s=1}^{S} C_{si}$. So, is obtained

$$\text{EANPV}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left[\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t} - 2\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right) - C_{\text{O}i} - \sum_{s=1}^{S} C_{si}\right]. \quad (43)$$

Equivalent Annual Profitability Index by use cases

Regarding the EAPI index, based on formulas (6) and (7) and taking into account the formulas for Profitability Index in each of Cases (a)-(f), one has

$$\text{EAPI}_i = \text{CRF}\cdot\text{PI}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\left(1+\frac{\text{NPV}_i}{I_i}\right), \quad (44)$$

where:

- for a purchaser (Cases c.3, d.2, e.3, and f.2), occurs $\tau_i = 0$. Thus, one has

$$\text{EAPI}_i = \frac{d(1+d)^{D_i}}{I_i[(1+d)^{D_i}-1]}\sum_{t=1}^{D_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t}, \quad (45)$$

where I_i is determined according to (15);

- for a developer in Case (a), occurs $I_i = C_i$. So, is obtained

$$\text{EAPI}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t}\Bigg/\left(\sum_{k=1}^{4} H_{ki}R_k - M_i\right); \quad (46)$$

- for a developer in Cases c.1 and e.1, occurs $I_i = C_i + \sum_{s=1}^{S} C_{si}$. Thus, one has

$$\text{EAPI}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t}\Bigg/\left(\sum_{k=1}^{4} H_{ki}R_k - \sum_{s=1}^{S} C_{si} - M_i\right); \quad (47)$$

- for a developer in Cases c.2 and e.2, occurs $I_i = C_i + C_{\text{O}i}$. So, is obtained

$$\text{EAPI}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t}\Bigg/\left(\sum_{k=1}^{4}H_{ki}R_k - C_{\text{O}i} - M_i\right); \quad (48)$$

- for a developer in Case (b), occurs $I_i = 2C_i$. Thus, one has

$$\text{EAPI}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t}\Bigg/2\left(\sum_{k=1}^{4}H_{ki}R_k - M_i\right); \quad (49)$$

- for a developer in Cases d.1 and f.1, occurs $I_i = 2C_i + C_{\text{O}i} + \sum_{s=1}^{S} C_{si}$. So, is obtained

$$\text{EAPI}_i = \frac{d(1+d)^{L_i}}{(1+d)^{L_i}-1}\sum_{t=\tau_i+1}^{L_i}\frac{P_{it}+\text{AA}_{it}}{(1+d)^t}\Bigg/\left[2\left(\sum_{k=1}^{4}H_{ki}R_k - M_i\right) - C_{Oi} - \sum_{s=1}^{S}C_{si}\right]. \quad (50)$$

3.3. Some of implemented use cases

IMNA Solutions use case

IMNA Solutions (IMNA) [36] is a technology company that specializes in developing innovative solutions aimed at enhancing healthcare delivery and patient management. One of the flagship products developed by IMNA is a comprehensive patient management platform that enables healthcare providers to monitor patient progress in real-time. 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.

Mobile apps were one of the proposed solutions. Using native mobile frameworks, because of security, data privacy, and smart device connectivity issues, mobile apps were discussed, developed, and finally delivered. After their implementation, the following results were obtained:

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 COVID-19 period.
3. Patients began to complete more often medical questionnaires and reach the end of medical trials, including:
   1) according to reports from Nasus Pharma [28], after using IMNA mobile apps, one of their last medical trials out of 1000 people it ended with 100% user engagement - a significant increase from the previously achieved maximum of 72%;
   2) according to reports from RambamHealth [28], after using IMNA mobile applications, one of their latest medical studies of 200 people ended with 98.5% user engagement - a significant increase from the previously achieved maximum of 67%.

To determine the economic impact, in Table 2, summary data obtained by IMNA are systematized.

Table 2

IMNA Solutions Cash flows for mobile apps in the 2019-2022 years [28]

Year	Income, USD	Costs, USD	Cash flows, USD
2019	97,400	133,900	-36,500
2020	98,800	130,100	-31,300
2021	284,000	141,800	142,200
2022	484,000	253,700	230,300

From Table 2, a trend of rapid growth in Cash flows can be observed, exceeding 230 thousand USD in 2022, over 1.6 times more than in 2021.

Securer use case

Securer [37] is an infrastructure for digitizing investors, assets, companies and funds ecosystems. Securer faced the following issues: 1) finding new auditory; 2) finding new communication and engagement channels; 3) to do more marketing and gain more attraction; 4) automate the Know Your Customer (KYC) process.

As a solution, the development of a mobile app was proposed. Using hybrid approach, because of planned and limited budget, the mobile app was developed and delivered. After implementing the mobile app, Securer received more insights about their products and services, raised the number of active users by 12%, achieves new engagement channel for further research, and obtains a proof of concept of mobile KYC [28].

VentureRocket use case

VentureRocket [38] is a comprehensive platform designed to streamline and enhance the processes of fundraising, investment management, and collaboration within the startup ecosystem. Aimed at entrepreneurs, investors, and accelerators, VentureRocket provides a robust digital infrastructure that facilitates the growth and development of early-stage companies by connecting them with the resources, capital, and networks they need to succeed.

VentureRocket was trying to extend their user engagement channels and reach new leads and users for their platform by: 1) finding new auditory; 2) finding new communication and engagement channels; 3) increase their reputation and branding; 4) secure their data against different potential issues.

In order to check and investigate a new communication channel and source of new users, the development of a mobile app was proposed. Using hybrid approach because of limited available developer resources during that period of time, the mobile app was developed and delivered. After implementing the mobile app with biometric verification layer, VentureRocket received more insights about their products and service, raised the number of active users by 9%, and achieved new engagement channel for further research [28].

4. Conclusions

The widespread use of mobile devices requires streamlining the development and use of mobile apps. In this context, it is imminent to evaluate the impact of mobile apps on business activities in particular and on the quality of life in general. Unfortunately, the

information, research and analytical data regarding the quantitative economic impact of mobile apps is poor.

In this paper, an attempt is made to improve the situation in the field. To this end, taking into account the categories of mobile apps in the Google Play Store and Apple App Store and the statistical classification of economic activities, a classification of mobile apps is proposed. This can help organizations promote and generate new types of income.

From the multitude of indices used to assess the economic efficiency of IT investment projects, the NPV, IRR and PI indices are selected, eventually in conjunction with the EAV method. These three indices form a Pareto set; the use of each of them, depending on the case, may lead to a different solution. Several qualitative indices have also been systematized to measure the impact of mobile apps.

To calculate the NPV, IRR and PI indices, the costs with mobile applications are essential. For this reason, six base cases were defined, and afterwards 12 sub-cases (more precisely, two base cases and 10 sub-cases) were defined and for each of them the respective formulas were obtained. Subsequently, based on these, the final formulas for calculating the NPV, IRR, PI, EANPV and EAPI indices were obtained for each of the 12 sub-cases.

Moreover, concrete calculations were performed regarding the impact of mobile applications developed and implemented within the companies IMNA Solutions, Securer and VentureRocket. These implementations confirmed the significant economic and social impact of mobile apps.

Conflicts of Interest: The authors declare no conflict of interest.

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