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CONCEPTUALISATION OF USING TECHNICAL DEBT TO MEASURE THE INNOVATION LEVEL OF NEW PRODUCT – SELECTED ISSUES

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Purpose: Conceptualisation of the technical debt use as the new product innovativeness measure.
Design/methodology/approach: This paper adopts the J. Highsmith perspective on the technical debt as the essential of agile project management. The presented customer centered perspective of product value allows to use the technical debt as base for the new product innovativeness parametrization. The presented approach is possible also with the behavioral conception of innovativeness being directly associated with the subjective customer perception and works to build theory accordingly. The research is entirely theoretical and uses two points of reference. The first was used to explore the possible use of the technical debt as innovativeness measure through the use of user function. The second, consisting of presentation the possible modification of F. Sgobbi value model as the management tool for analyzing the value of new technology based product.
Findings: The Concept of technical debt use as the measure of technology value is presented.
Research limitations/implications: Future research sugestions will concerne the discretization of presented concept.
Practical implications: The Presented conception may became the an interestning base for analyse and assesement of innovatives products and also in this way it can be used for new management tool designing, particulary in the domain of value based management process.
Originality/value: Elaboration and operationalization of new technology based products model development with application of technology life cycle.

Keywords: technical debt, innovativeness, new technology based product value, use function.

Category of the paper: Conceptual paper.

1. Introduction

Today's economic dynamism depends to a large extent on the entrepreneurial spirit of a company. Saturated markets are no longer a prospective source of its growth. New markets need to be developed by creating new customer needs. Entrepreneurs are increasingly looking for an opportunity to increase the value offered to the customer by creative diversification of manufactured goods. Such creativity should translate into effective commercialisation of new products, which will strengthen the company's market position. J.A. Schumpeter considers business innovation (Schumpeter, 1960) a prerequisite for accomplishing such a vision of development. Innovation level today affects customer perceived value, measurement of which can be a very interesting research area. Consequently, F. Malerba draws attention to the evolutionary aspect of innovation linked to the cyclical vision of economic development, stressing the importance of its dynamics (Malerba, 2006).

The possibility of measuring innovation of a new product using technical debt is therefore an important research objective outlined in this paper. Management practice indicates the need to conceptualise such a quantifying tool, which will, among others, identify the financial resources necessary for the effective introduction of new technologies to the market.

In a preliminary manner, the paper presents the nature and scope of technical debt, its application and changes in its value over the course of the new product development process. A description of the possible use of the technical debt of a use function to measure the level of innovation of the product is provided. The paper also describes the relationship between the use function and technical debt of a technology, basing on the latter's life-cycle model. This justifies linking the concept of innovation level to the size of technical debt of a technology. Consequently, on the assumption that a certain amount of technical debt determines the level of technological innovation and the level of technology translates into technology value, the paper presents a modification of the F. Sgobbi model estimating technology value. The modification enables linking the innovation level with technology value.

2. The importance of technical debt in the development of a new product

In most innovative companies or innovative projects, given their initial phase, the practice of financing them is based on an increase in external debt, which in extreme cases can be converted into equity, becoming an important element in the estimation of project or company value. Limited access to the sources of funding and high costs of debt service put a constant pressure on reducing operating costs and meeting accepted commercialisation deadlines. The drive to increase competitiveness and attractiveness of the products offered to customers

forces companies to strive for continuous innovation, no longer anticipating market behaviour but embracing adaptive innovation to meet customer needs (Loch, and Kavadias, 2008).

Adaptive innovation, however, runs counter to the classic management process that usually focuses on planning, business strategy, or budget. According to J. Highsmith, evolution and adaptation based approach cannot be synonymous with planning and optimization. Innovations are subject to the same principles as living organisms – they mutate, survive, develop, and thrive (Highsmith, 2009). This principles should also be adopted when designing new products, and their absence means that there is a significant gap in the company between the need to offer new and therefore innovative products and the real possibilities of delivering them to customers.

Despite some similarities, technical and financial debt are two different concepts. The main difference is the definition of the interest rate on the debt and the inevitability of its payment. By creating technical debt, the company makes a trade-off between quality and productivity. On the one hand, in the short term, the costs of maintaining product functionality or production costs are reduced for the time being, on the other hand, despite present benefits, there will be cost implications in the future. The analysis of these dependencies is an important decision-making issue affecting the functioning of the whole company (Alves et al., 2016). The concept of technical debt was introduced into IT management practice in the 1990s by W. Cunningham and is gradually gaining increasing attention not only in this sector (Codabux et al., 2017). The origins of this concept are related to a situation where the project carried out is not properly supervised and there is considerable time pressure to complete it (Martini, and Bosch, 2017).

Technical debt can already appear at the very beginning of the project and is defined as the gap between the current costs of making changes and optimal costs. The control of technical debt level allows determining the trade-off between the current benefits offered to customers and meeting their expectations in the future.

Any decision to change technology has financial consequences in the future, today's emergence of technological debt requires its repayment in the future, which will limit the decision-making possibilities. Thus, its growth or decline today is crucial for the future financial situation and could translate into the company's future competitive position (Guo et al., 2016).

J. Magnusson and B. Bygstad B. developed a model for the process of creating technological debt based on exante assessment and expost investment decisions on the introduction of new technologies. This type of decision-making process is based on three basic concepts: the past, current, and future technological state of the company. The past state describes the changes in the company's technological resources in terms of trends and practice of the time, as a result of the influence of the surroundings on managing these resources. The current state is today's technological infrastructure and all processes and organizational resources, and the future state is the assumed level of technological potential resulting from the institutional logics adopted by the company. Based on the concept of technical debt used by programmers, the concept of technological debt has also been defined. The starting point for defining its concept is the recognition that the emergence of corporate debt is linked to company

development and is the normative component of liabilities and the result of managerial decisions. Technological debt can therefore be defined as future expenditure caused by today's measures to reduce the costs of commercialising new technology. Neglecting the development of documentation, schematic diagrams, standards, and procedures and the absence of the prototyping process are among the actions overlooked due to market pressures. Like any other, technological debt is also fraught with interest rates and payment dates in the future (Magnusson, and Bygstad, 2014). This approach only makes it possible to determine the investment levels necessary to achieve the assumed technological capacity by analysing the benchmarks presented by other companies. However, it does not make it possible to determine the value of technology as it is linked to the market and customers' perception of the products based on this technology.

Using software industry as an example, it can be observed that the costs of making changes increase slowly during the first years, and then their amount goes up rapidly, which leads to frequent abandonment of product development. The constant emphasis on reducing working time and spending leads to instability and rising costs of introduced changes. Rising technical debt reduces the ability to respond to customer needs, which makes them confused why minor modification requires a long implementation period. Customers typically want more use functions to be added as soon as possible, and trying to meet their needs leads to an even greater increase in technical debt in an ever-decreasing time. Then, the measures taken to reduce the amount of this debt are becoming more and more costly for the organization, not translating into an increase in the benefit to the customers, but only into maintaining the value offered to them so far. The fact that technical debt appears in the early stages of product development is important because it is not advisable to reduce it too strictly. It is at this stage that technical debt should reach its optimum value when the time pressure and the level of costs incurred are adequate to the expected results (Ampatzoglou et al., 2015). Therefore, taking corrective action as early as possible is logical and provides a future framework for controlling technical debt. Based on keeping the cost of change low, the continuous reduction of technical debt is often the reason for creating a company's technology strategy that includes a description of the structure of the value creation process. This technological strategy is based on the analysis of the consequences of the work carried out with regard to the two possible time perspectives of company value creation, short-term and long-term.

The aim of adopting such a concept of development is to enrich the management process with aspects related to the quality of the systems being developed, in particular with regard to the benefits offered to end-users (Kraft, 2012). Such a decision-making process would require the quantification framework for the estimation of technical debt. This was originally the basis for an initial concept of such a model for information technology (Nord et al., 2012). The initial assumptions of the model are based on the use of the costs of redevelopment of a given system (e.g. IT design), resulting from the introduction of each new E_i element, which is usually another use function of the system introduced into the nth version of the product.

Then T, the total cost of version n, will therefore be a function of the implementation and redevelopment costs, i.e. C_i and C_r:

$$T(E_1, \dots, E_n) = F(C_i, C_r), \quad (1)$$

where: $C_i = \sum_k C_i(E_k)$ and $C_r = \sum_k C_r(E_k)$.

The model assumes that the implementation and redevelopment costs are added together. Implementation costs are counted as: $\sum_k C_i(E_k)$ for all new E_k elements, where implementation cost $C_i(E_k)$ is provided for all elements of architecture k. However, redevelopment costs C_r for the nth version are calculated in a similar way: $\sum_k C_r(E_k)$ for all new elements E_k, where the redevelopment cost $C_r(E_k) = \sum_j C_r(E_j)$ for all existing E_j elements. However, if E_j is already present in the previous edition of the product, $C_r(E_j) = D(E_j, E_k) \cdot C_i(E_j) \cdot P_c(n-1)$, then $D(E_j, E_k)$ is the number of links between E_k and E_j, C_i are implementation costs of E_j, while $P_c(n-1)$ is the level of prevalence of the n1 version change, specifying the percentage of elements (use functions of the product) of the system undergoing change.

The dynamics of product distribution therefore make it possible to determine the number of system components that are subject to change caused by the introduction of the new use function. The above-presented conceptualisation of the costs that make up technical debt is linked to an increase in the functionality of the product, usually perceived by the customer as a new use function. Similarly, the same reasoning may be applied to expenditure relating to the estimation of the incurred technical debt. Differentiation and diversification strategies can therefore be translated into an increase in the use functions offered by new products. In turn, innovation is the basis for the development of new products and services and a source of value for customers and entrepreneurs. New ideas translated into innovation after effective commercialization are currently the main tool for the development of the product, but they also become a development impetus for manufacturing systems (Taura, and Nagai, 2017).

According to G.A. Akerlof and R.J. Shiller, the importance of innovation has changed significantly from a production efficiency tool to a technical development stimulator (Akerlof, and Schiller, 2017). It is because the development of the economy is not based solely on increasing production volumes, but on the ability to make effective use of innovation. Changes may also lead to the conclusion that innovation as such is not sufficient to sustain economic development. The ability to create demand for new innovations is therefore becoming an important issue. This ability will refer to the skilful impact on the sphere of perception of the future customer, thus creating the value of innovation (Kumar, and Sundarraj, 2018). The creation of the value of innovative products is characterized by the full subjectivity and persuasive nature of the impact on the potential customer (Wooddall, 2003). The value of innovation to the customer described in this way is a holistic concept, but at the same time a concept of highly individualised importance. One of the conclusions is that the value of an innovative product to the customer should be objectively quantified in order to objectively

assess the effectiveness of the commercialisation processes carried out in terms of optimising that value.

If new technology is behind an increase in the efficiency of manufacturing systems, then it is also a basis for the development of new products. This also generates interest in possible practical ways of determining new technology value, especially in terms of market development caused by technological progress. This mostly concerns a particular company or even a new product based on the use of such technology. However, the value of new technology is not an unambiguous or easy-to-quantify concept, as it includes a number of non-standardised factors that are unreasonable from the scientific perspective.

3. The level of new product innovation and the dynamics of the technical debt of new technologies

The most widely accepted way of describing technological development is a model based on radically new technology whose novelty makes the existing state of competence outdated. Radical innovation as the foundation of new technology is further refined to optimise its manufacturing and market characteristics (Petric, and Echols, 2004). The result of this process is the creation of dominant design that later becomes the standard for a given field, and only undergoes an incremental changes. This results in two ways in which innovation affects organisational competence. In the case of radical innovation, competences quickly become outdated, the rules of the game in the sector are changed and competition to establish their new form intensifies. On the other hand, incremental innovation in the development of technology leads to the development of organisational competences already possessed.

Since the quality of the competences translates into the market behaviour of the company, it can be concluded that the process of developing a new product must be carried out taking into account the dynamics of technological evolution. The use of prosumption in the company in relation to the course of the innovation process makes it a major challenge to accurately identify new use functions of the product in response to future user needs (Keinonen, and Takala, 2006). In this case, it will be important for the company to set up a portfolio of new products based on the use of innovations, taking into account future modifications to their structure by introducing new use functions, especially those that result from the use of new technologies.

Developing the concept of cognitive ease, D. Kahneman provides the basis for a stricter definition of the concept of innovation in relation to technical debt (Kahneman, 2012). Cognitive ease can be linked to a sense of comfort resulting from the use of a given product. A sense of comfort increases the satisfaction resulting from the use of the product, which causes a sense of its increasing value perceived by the customer. The concept of innovation presented here is subjective and refers directly to the behavioural trend in the process of value creation.

Cognitive ease means that there is nothing new that requires mobilisation and concentration, i.e. the perceived value of the product is optimal and its innovation is perceived favourably. This perception is achieved when technical debt level is possible to determine. The opposite of such a condition will be cognitive effort, that is to say, a sense of discomfort. It results in a decrease in satisfaction and a decrease in the perceived value of the product. Its innovation is then assessed negatively, which results in cognitive effort to reduce the negative debt that has been negatively felt. Unlike cognitive ease, cognitive effort will mean the need to mobilize and concentrate, as there are new needs to perform certain activities in the use of a given product. In a state of cognitive ease, the user will concentrate on cause-and-effect and relative holistic approach. Feeling cognitive effort increases the feeling of alertness and suspicion and leads to mental exertion, which means that the customers will make fewer mistakes, but the use process will become less intuitive and creative for them. Both concepts introduced by D. Kahneman are multifaceted. Hence, the possibility of linking them to the concept of product innovation or technology understood as the relationship between the user and the object used. This notions of innovation are dynamic and change over time.

New technology that has been successfully introduced to the market should create a state of cognitive ease in the user, due to a number of factors. These factors may be due to the characteristics of innovation or may be a result of an intentional pressure on the user, unrelated to the essence of innovation (Rampino, 2011). The ongoing use might result in a state of cognitive effort resulting from a growing awareness of imperfections in the functioning of technology and from the need to modify it. It might mean a decrease in the innovation of the product or technology. The emergence of a state of cognitive effort is an important moment in the proposed concept of measuring the dynamics of innovation level, a moment of the emergence of technical debt. That assumption therefore makes it possible to determine the rate at which the user perceived innovation is declining and to determine the necessary inputs to maintain that innovation at the level expected by the company. Such broadening and enrichment of the concept of innovation enhances its capacity to shape it, and its link with the concept of technical debt or technological debt makes it possible to define the determinants of the financial strategy for the technological development of the company.

When new use functions are offered, customers often appreciate innovation and respond positively to the value presented by the company. As a result of this process, the number of effective commercialisations of new products is increasing, resulting in an increase in the company's development potential (Schulz et al., 2013). This approach makes innovation one of the most important strategic factors and reflects the flexibility and adaptability of the organisation.

Innovation measurement and analysis are a key to determining the effectiveness of applying new technologies not only to the products offered, but also to determining the configuration of the company portfolio. This is particularly important in the case of the expected high market dynamics, when the company should assume the use of new technologies (Mui Di Benedetto,

2011). In addition, such an analysis should take into account the future financial effects of new technologies and those new use functions that are possible to identify. This becomes an interesting challenge for the decision-making process determining the effectiveness of the commercialisation of a new product or its innovation (Artmann, 2009). Customers are not aware that they are receiving a new product with technical debt. As a consequence, they undergo various experiences in the use of the product and are confused unable to assess its quality.

Gradually, the debt begins to increase (Fig. 1). Other participants of the value chain aim to minimise technical debt, hence the need for more versions of the product with its reduced value. This would be happening slower than if technical debt had been reduced from the outset. However, these activities will be limited in terms of the propagation of technical debt along the entire chain, and a significant part of it may therefore be frozen. For the customer, this will mean a loss of value associated with the use of the product (McGregor et al., 2012).

Therefore, the concept of the analysis of a product as a set of use functions is interesting; each use function is due to the new meaning given to innovative technology and its life cycle phase (Filipowicz, 2018). This approach is based in part on the concept of product modularity and then becomes the basis for the conceptualisation of innovative products in the company. The idea of modularity can be formalised at the product level (P) as the sum of use functions offered to the customer, calculated as the sums of vectors $P=\sum_{i,j}^{n,m}\overrightarrow{Fu}(dt_i, cpv_j)$. Each use function is defined on a vector composed of technical debt resulting from its technology (dt) and its customer perception value (cpv).

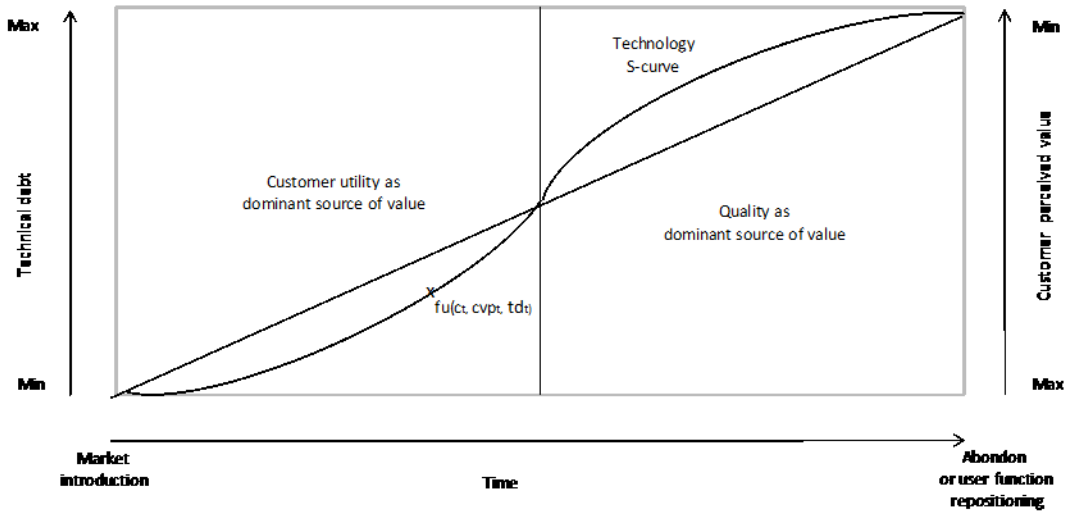

Figure 1. Conceptualisation of the evolution model of the use functions of a product based on the application of new technology. Source: Filipowicz, P. (2019). New product conceptualisation trough the technology based use function reconfiguration. *International Journal of Innovation in Management, vol. 7, no. 2*, pp. 81-87.

It is also possible to imagine new use functions whose market offer will result from the use of new technologies. In the extreme case, the mix of new functions will be a base for the concept of an innovative product in technological terms (Filipowicz, 2019). The proposed approach enriches the conventional perception of the product model and can be used in a pro-customer perspective. Product structure modelling based on the use of new technologies can become an interesting direction for the company to seek market advantage, based on the optimization of technical debt of the product's use functions. As a result, it will result in the possibility of configuring the entire company portfolio, which will give an opportunity to monitor the dynamics of technical debt of individual use functions of products. The question of determining technical debt for new technologies commercialised through a product offer therefore arises further, in particular as regards the possibility of financing the commercialisation of new technologies by the company.

4. Technical debt of a product use function as an indicator of innovative technology value dynamics

For the efficiency of the investment process, it will be particularly important to determine the level of innovation for new products based on the use of a new technology in the initial phase. From a market perspective, start-up technologies are characterised by being completely different from previous ones, with limited market use and a limited number of users. These technologies may become generic in the future and are therefore seen as a very interesting subject of economic analysis that clearly justifies the need for their development. Determining the level of their innovativeness and the dynamics of its decline, from a market perspective is most expected, especially given an increase in technical debt of the whole product. An interesting starting point for such an evaluation may be a modification of the model of extended value (Sgobbi, 1995). The modification of this model is intended to include the importance of the technical debt resulting from the use of new technology in relation to the use functions of the new product.

Such a model will aim to optimise the amount of technical debt of the new product by configuring the use functions according to the expected benefits at a given stage of the sales process. It will therefore be appropriate also to be able to evaluate the innovation of individual new technologies in terms of the product as a whole. This will give a better opportunity to adapt it to customer needs as well as to economic and time resources available to the company (Buchmann, 2015). The level of innovation of the product and its quantification cannot be determined on the basis of statistical data since there is a lack of historical values and comparative analogies, especially in the case of the design of a new product involving new technologies.

All these limitations and challenges are analogous to attempts to determine the future market value dynamics of such products, hence an interesting prospect of modifying and using the extended value model as a model of extended technical debt. It is therefore a question of determining the level of innovativeness of a product offering several use functions derived from the use of different technologies with different technical debt value. Extended technical debt will entail the expenses necessary to adapt the new product to customer needs, on the assumption made in accordance with J. Highsmith's theory. It is assumed that the newly offered product has very high innovation, which decreases with the emergence and accumulation of technical debt. This accumulation is the result of customer response reflecting the expectations of specific modifications to adapt this product to increasingly specific needs. In line with the above concept, it is assumed that product innovation decreases as knowledge of the practical possibilities of restrictions on new innovative products increases. In this way, the predefined volume of the extended technical debt (PDT) of a given technology can be expressed as (2):

$$PDT_{i,j} = f_{i,j}(DT), \tag{2}$$

where:

$PDT_{i,j}$ is a matrix of applied technical debt resulting from the first application of a given technology for the jth use function ($i = 1, 2, \dots, n; j = 1, 2, \dots, m$),

DT is the vector of expected net technical debt associated with the ith technology, hence $DT = [dt_1, dt_2, \dots, dt_p]$.

The identification of net technical debt as the sum of technical debt and its reduction by synergies from the use of other technologies linked to the introduction of new technology will be based on the detalization of PDT matrix recordings. Technical debt formalisation, as proposed by F. Sgobbi, will consist in adopting the criterion of discounted cash expenditure to calculate net updated value as a means of expressing PDT in a formula (3):

$$PDT_{ij} = \sum_{t=1}^{N} \frac{f_{ij}(DT_1, DT_2, \dots, DT_p, t)}{(1 + r_t)} \tag{3}$$

or in matrix form:

$$\begin{bmatrix} PDT_{1,1} & \cdots & PDT_{1,m} \\ \vdots & \ddots & \vdots \\ PDT_{n,1} & \cdots & PDT_{n,m} \end{bmatrix} = \sum_{t=1}^{N} \begin{bmatrix} \frac{f_{1,1}(DT_1, DT_2, \dots, DT_p, t)}{(1 + r_t)} & \cdots & \frac{f_{1,m}(DT_1, DT_2, \dots, DT_p, t)}{(1 + r_t)} \\ \vdots & \ddots & \vdots \\ \frac{f_{n,1}(DT_1, DT_2, \dots, DT_p, t)}{(1 + r_t)} & \cdots & \frac{f_{n,m}(DT_1, DT_2, \dots, DT_p, t)}{(1 + r_t)} \end{bmatrix}$$

where:
$f_{ij}(DT_1, DT_2, \dots, DT_p, t)$ is the cash expenditure resulting from the use of jth technology for the ith use function during the tth period of technology offering,
r_t is a discount rate for the tth unit offering period (e.g. for the year t = 1, 2, ..., N); N is the number of periods of offering a given technology.

Further, in order to maintain the correctness introduced by the original model, the proposed entry will still have to allow for the limitation of the data taken into account to quantitative variables. Such simplification is desirable for the use of such a defined concept for optimising the investment plan related to the introduction and development of new technology. The flow-through interpretation adopted here still needs to be specified as the proposed reformulation of the model is based on an estimate of expenditure resulting from the dynamics and possible coverage of resulting technical debt. The presented approach based on extended technical debt helps to determine the decline of commercialized product value derived from the loss of its innovativeness for the customer. Also it's the makes possible to estimate the indispensable investment to finance the effective adaptation of concerned product to the client expectations.

5. Conclusions

The initial measurement concept of technical debt presented as a tool for measuring the level of product innovation makes it possible indirectly to parameterise the innovation of new technology indirectly. The measurement of its level in both cases is based on the more popular modular structure of the product and points at the customer as an exogenous source of perceived innovation, which refers to accepted trends. The concept of technical debt is thus becoming worth more detailed analysis and broader research in terms of the economy of the company. The development of its possible applications can have a significant impact on a reliable and accurate measurement of innovation dynamics and contribute to increasing the effectiveness of decision-making processes in the field of technological development. The decision-making uncertainty that accompanies the development of these technologies is also becoming important for the development of the concept of the use of technical debt.

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