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MODELİNG OF İNNOVATİON PROCESSES

Abstract

The article examines models of the innovation process and reveals the essence of each generation. Here the stages of the innovation process are examined, and a classification of innovation processes is also given. The economic growth model takes into account the technology to stimulate production, as well as current investments.

Key words: *innovation process, model, economic growth, investment.*

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In the specialized literature, the five generation models of the innovation process are defined as the basis, then they are changed and completed with various modifications in relation to and taking into account the current experience of innovations[1].

The first generation models of the innovation process are the so-called "technological push" models. Another name for these models is "linear" or "neoclassical". They were dominant from the mid-1950s to the late 1960s[2]. In these models, the innovative process was considered as a "discovery process in which new knowledge is transformed into new products through certain stages" [3]. Thus, in order to obtain results in the form of new products or services, it was necessary to concentrate efforts in the first stages of the innovation process in scientific research design work. The process of translating results into new products, services or processes was automatic and lacked attention. The result of this approach to the innovation process was increased attention to the creation of scientific laboratories (Figure1).

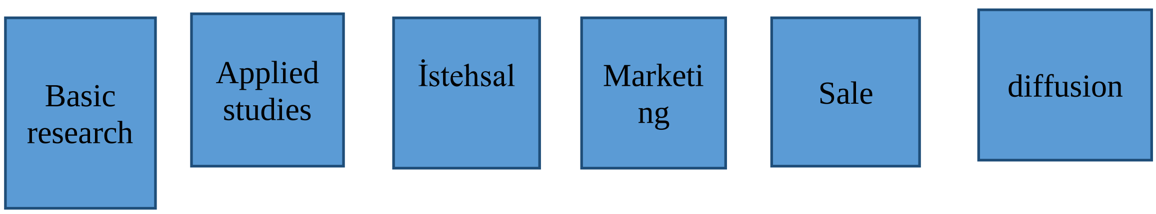

Figure 1. Stages of the innovation process

The process of diffusion of innovations is called technology diffusion. The rate of diffusion largely depends on the effectiveness of the technological innovation. Moreover, the more companies that use this innovation, the more companies that do not [4]. In the mid-1960s and early 1970s, a second generation of models called "demand-driven" appeared. (thedemandpull). Innovation was the result of signals from the market; unlike the previous model, innovation is no longer Theo result of new ideas coming from ETI, but has begun to meet demand from consumers (Figure 2).

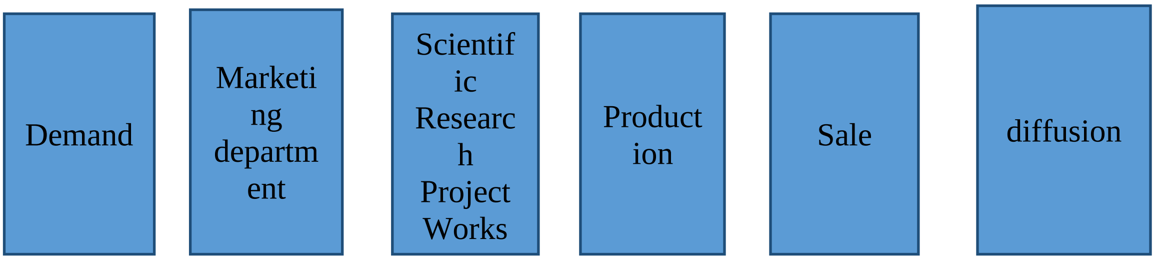

Figure 2. Sequence of "second" generation stages of innovation process models

In a certain sense, the second model of innovation can be called "reactive", and the neoclassical model can be called "pro-active". Subsequently, increased competition and shorter product life cycles have led to the need for closer links between research and other stages of the innovation process.

This led to the emergence of a new (third) model of the innovation process after the publication of the "Evolutionary Theory of Economic Changes" by Nelson and Winter [5] and the "Interactive Model" by Rosenberg and Kline [6].

Then the innovation process begins to be considered as a combination of the previous two models. In this model form, called "interactive models", new knowledge was combined with old knowledge (Figure 3).

This model emphasized the need to strengthen relations between different departments of the enterprise. It was believed that new ideas can be generated from any department and therefore interaction between different departments is an integral part of the innovation process.

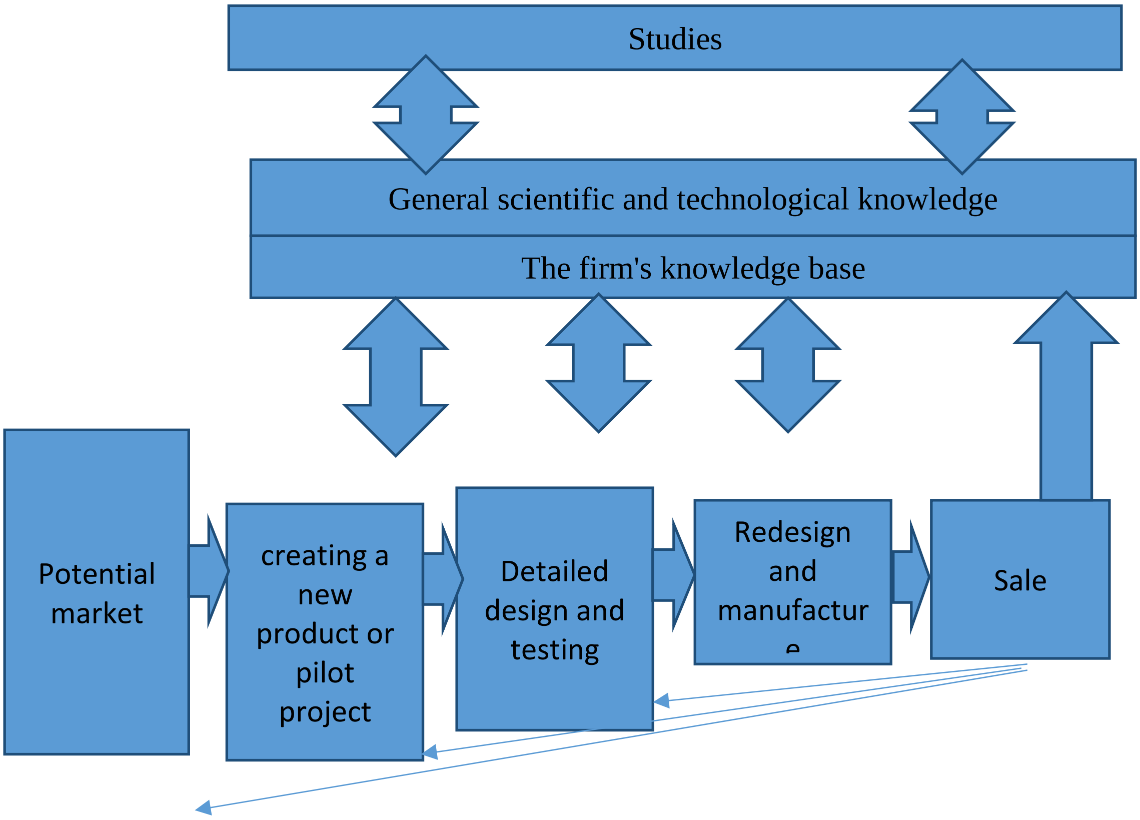

Figure 3. The third model of the innovation process

Only when the current level of knowledge cannot solve their technological requirements (requirements) does the creation of new knowledge (through R&D) begin. The interactive model remains linear in one way or another. In the mid-1980s, the new organization of production in Japanese enterprises led to the emergence of new, fourth-generation integrated innovation process models [7].

Different divisions of an enterprise combine to create a new product, allowing the enterprise to reduce costs while reducing product development time. At the same time, horizontal cooperation (creation of joint ventures, strategic alliances) has increased significantly.

In the 1990s, the focus of economists shifted from integration to networking. It was believed that in order for the enterprise to be innovative, it is necessary not only to unite the various departments of the enterprise around the innovation process, but also to create and strengthen their network interactions with consumers, suppliers and other institutions.

This formed the so-called "innovation system" [8]. In this decade, "systems of innovation theories" [9] appeared. The main idea of these theories was that the interaction and exchange of knowledge not only between different departments of the enterprise, but also among other should be carried out with "sources of knowledge" (enterprises, universities and research centers, consumers, suppliers).

Freeman(9) defines an innovation network as “a limited number of open connections with preferred partners to reduce static and dynamic uncertainty”(10).

Despite the existence of informal network relations, they are practically not described and studied in the works of that period, because "they are difficult to classify and measure". Rothwell(11) described this innovation model as follows: Certain transformations in managerial, organizational and technological spheres allow the enterprise to change the speed of change and the effectiveness of innovation.

Rothwell identified the main strategic elements and characteristics of the fifth innovation model (Table 1).

In the fifth generation innovation process models, electronic means to strengthen internal and external relations of the enterprise - information and communication technologies (ICT Information and Communication Technologies); special attention is paid to the use of relations between different departments of the enterprise, intercompany relations and relations with other institutions. Information sharing was key to the innovation process. ICT is a necessary element of these models because information is a key factor in the innovation process.

The importance of information and data in the innovation process has led to the creation of a large number of IT solutions that facilitate the storage and exchange of information. However, it soon became clear that information and data were only one of the many elements needed in the innovation process, and that competitive advantage rested largely on the other element—tacit knowledge, which is the basis for sixth-generation models of the innovation process.

Table 1

Strategic elements and characteristics of the fifth model of the innovation process

Strategic elements	Features
Time based strategy	Higher organizational and system integration
Paying attention to quality and other non-price factors - total quality management (Total quality management)	A flexible organizational structure that allows you to quickly react to changes
Corporate flexibility	A fully developed database
The consumer is the most important link in the strategy	Effective external communication channels
Strategic integration with key suppliers	
Horizontal technological cooperation strategies	
Electronic Data Processing Strategies	

As stated by Carlsson and Stankiewicz, enterprises differ from each other according to the information they have, the intensity of using the knowledge they have, how they use this knowledge, how they exaggerate it and how they learn[12]. The more innovative enterprises, and therefore the more competitive enterprises, are those that are able to create, retain and use their knowledge most efficiently. It follows that enterprises differ in what knowledge they have and how they use it.

The innovation process continues to be a network-integrated process, but in contrast to the previous model where information sharing through ICT was the focus, more attention is paid to the mechanisms that enable the creation, dissemination and use of all types of knowledge (Table 2).

In the late 1990s, interest in rapid learning emerged and began to grow as an enterprise's key source of knowledge and competitive advantage. The faster he can learn, the more innovative he is, the more capable he is of reacting to market changes. Everything related to strategic learning can be called the sixth model of the innovation process.

Table 2

Strategic elements and characteristics of the sixth generation innovation process models

Strateji elementlər	Features
Time and space are limited	Flexible structures and mobility of resources
Emphasis on intangible assets as the main resources of the enterprise	Effective mechanisms for internal and external knowledge sharing
Emphasis is placed on communication skills	Senior management involvement
Co-owners are an important part of the strategy	Language and culture
Strategic integration with competitors	Relations with foreign enterprises
Focusing on tacit knowledge	Identification, measurement mechanisms, management of intangible assets

Thus, the approaches to the innovation process change depending on the demands of the market and the economic environment[13]. The above-discussed models of the innovation process were consistently provided with economic and mathematical tools - model and methodology - in the process of developing the theory and practice of this issue. In this aspect, existing approaches allow covering innovation processes of different scales - from the level of the country and economic sector as a whole to the level of the company. Modern research areas of innovation processes can be classified as follows [14]:

Economic growth models. Research related to this approach is focused on the study of factors affecting the growth of production, such as investment strategies in the development of new technologies. The fundamental importance of this factor is determined by both its strength and relative short-term impact on production. Consider the model of economic growth. The model takes into account two main trends: on the one hand, technology (accumulated annual investments) stimulates production growth, on the other hand, current investments consume part of the resources from the production sector. The model is described by a differential system.

$$Y(t)/ Y (t)= f_1 + f_2 (T(t)/Y(t))^y – g *R(t)/Y(t)$$

$$T(t) = R^1 (t) = R(t- m) – σ T(t)/ 1 – σ$$

Here Y(t) is the total annual production, T(t) is the technology collected in production, R(t) is the current (annual) volume of investments in the development of technology, f 1 is the growth rate of endogenous production, f2 (T (t)/Y (t)) y - the increase in the growth rate of production due to the collection of new technologies, g* R(t)/Y(t) - the factor of slowing down the growth rate of production due to the withdrawal of funds from the production sector, m - the total time of commercialization of developments, σ - the coefficient of "obsolescence" of the accumulated technologies.

In a simplified analysis, the parameters σ and m can be neglected and set equal to zero. In this case T(t) ≈ R(t) .

Production Y(t) and technology T(t) are the main variables of the model. Current investments R(t) and technology development are not predetermined. The problem is to find the optimal law of investments R(t) as a function of time. As a criterion of optimality, the utility function U, presented in the form of an integral consumption index with a coefficient, is taken.

$U = \int e^{-p(t-t0)}$ 1n D (t) dt D = D(t)= ($\int x^a (j)dj)^{1/a}$

$X(j) = Y(t)/n(t), n(t) = be^{ks} T(t)^{\beta_1} R(t)^{\beta_2}$

Here D(t) is the consumption index, t is the current time, t0 is the initial moment of time, α, β 1, β2 are the elasticity coefficients.

The infinite upper limit of integration means that investors are interested in long-term growth prospects.

1) Diffusion and absorption of new technologies. Over the past decade, economic growth has been greatly influenced by the ability of a firm, enterprise or country to adopt the latest technologies created by global technology leaders. The purpose of models in this area is to determine the role of technology adoption in innovation, to model different scenarios of investment of limited resources in innovation, and to prepare recommendations for innovation optimization based on the obtained results.

Let's consider the model describing absorption. Suppose that firm B produces a certain product, and the level of technology used by firm B in the production of this product is characterized by the value of nB (t) at each moment of time t. Suppose that the technological leader in the production of this product at time t is firm A, and the technology level of firm A is characterized by the value nA(t).

In this case, at the initial time t0 = 0, the value of nB (0) is significantly less than the value of nA (0). We will consider that the process of innovative development of a technological leader is continuous and its speed is proportional to the technological level achieved. Technologically consistent (firm B) invests available limited resources 0 ≤ LnB (t) < L in the development of technology, and the rest of this resource in production L - LnB (t), firm B absorbs the technological leader by a certain ratio 0≤γ(nB) ≤1technologynA(t). The parameter γ(nB) characterizes the technological follower's ability to adopt the technology.

Management is carried out by investing the resource LnB (t) of firm B in the development of nB technology. It is assumed that the growth rate of nB (t) in firm B is proportional to the existing technological level consisting of nB (t) and own level nB (t) + γ(nB)nA(t), which is the absorbed technology γ(nB)nA (t) is also proportional to the consumed resource LBn (t).

Thus, the process of technology development in the company is described by the following relations:

nB = LBn (nB + γ(nB)nA), nB(0) = n0B

Processes described by equations of this type are sometimes called technology diffusion processes. Here we deal with the process of diffusion of technology nA(t) from technology leader A to technology follower B.

Let the quality of the resource investment at each instant of time t be evaluated by the value D(t) (profit), which depends as a power function on the achieved level of technology nB (t) and the achieved production volume. At this time, the volume of production is proportional to the share of L - L Bn (t) resources invested in production.

Thus, the profit at each instant of time t will be:

$D(t) = d(n^B(t))^{\beta 1} (L - L_n^B(t))^{\beta 2}$

Here d>0, 0< β1 < 1, 0 < β2 < 1– are a set of parameters.

We choose the general specific rate of profit growth of firm B as the objective function J characterizing the quality of the investment policy LnB (t):

$J = \int e^{-pt} * D(t)/D(t) * dt$

Here p is the discount rate. The management task facing firm B is to maximize this objective function. It is equivalent to an optimization problem that is more suitable for this task.

$J = \int e^{-pt} 1nD(t)\, dt$

Thus, we obtain the following optimal control problem for the follower of firm B:

$$\begin{cases} n^B = L_n^B(n^B + \gamma(n^B)n^A),\ n^B(0) = n_0^B \\ n = g^A n^A,\ n^A(0) = n_0^A \\ 0 \le L_n^B < L \\ J = \int e^{-pt} 1n\, D(t)\, dt \rightarrow \max \end{cases}$$

Numerical experiments conducted while studying this model allow us to draw the following qualitative conclusions about the optimal investment strategy for innovation. At the first stage, the company's technological level.

At a significantly lower level of technology, the focus is on getting to that level as quickly as possible. At the same time, the share of investments in innovation activity can occupy a significant part (more than 50%) of the used resource.

As you approach the level of the technological leader, this share decreases to the level necessary for the adoption of the latest technology (up to 12%). In this case, the original developments are practically impossible to fly.

he main part of the used resource is directed to the production of a technological product that corresponds to the world level. The models considered in the conditions of economic instability are of high application importance. The economic growth model reflecting investment strategies in the development of new technologies allows to determine the need and volume of investment in technology.

This is especially important in unstable times, when there is a shortage of investment funds and it is necessary to determine the most profitable areas of investment and calculate the benefits of these investments. These questions can be solved by the economic growth model by finding the utility function U.

Also, the diffusion and absorption model is of high practical importance in the unstable period. In the conditions of lack of own resources. in times of crisis, individual firms may pay part of their L funds to abandon production in order to invest in new technologies.

Under these conditions, the importance of the possibility of borrowing or absorption of technologies already developed by one company from another (technological leader) and further spreading of this technology - diffusion increases.

It is clear that the technological leader will gain more profit due to the advantage of using new technologies, but for the firms adopting new technology, it is important first of all to maintain the latest market trends in their production and not to be left behind. The resources released by the adoption of currently developed technology can be used by the follower firm to maintain the required global level of commodity production.

The feasibility and importance of the adoption and diffusion of new technologies can be considered from the perspective of enterprise scale. In small businesses, the opportunity to adopt new technology from the technology leader is one of the most acceptable and possible ways to keep up with the latest trends in the production of goods and therefore stay in the market.

Since small enterprises have a rather small amount of their own resources (L), they often cannot allocate part of the resources involved in production to invest in new technologies, because this may lead to the stoppage of production.

In the modern conditions of fierce market competition, the impossibility of using the latest technologies in production can lead to the bankruptcy of the enterprise in a short time, but since small enterprises do not have their own funds to carry out their own development, the most realistic ways to solve this problem are to adopt technologies from enterprises that are technological leaders in a certain field.

Also, small businesses tend to integrate and implement new technology more quickly because the technology has fewer problems to solve than a large enterprise, meaning self-implementation is faster and requires less staff training.

But the main challenge for small businesses is the ability to find technologies that will allow them to adopt from a technology leader without significant costs, and at the same time directly meet the needs of a particular small business.

Medium-sized enterprises may already have such a situation that they can invest part of Ln (t) funds in investments in new technologies, while the level of the remaining production resources will allow L - Ln (t) to continue production.

But at the same time, in a situation that allows the adoption of a new technology, it is possible to save money that can be used for the development of a new technology, since this technology is adopted at a lower cost. These released funds can be additionally used in production, which will help to maintain production at the required global level.

As for large enterprises, they can carry out their own development and invest enough funds in innovation; They are, as a rule, very technological leaders in their field, which allows small medium enterprises to adopt their new developments. When studying the approaches and methods of management, as well as when synthesizing the management system, it is necessary to use specific techniques of the sciences that study the phenomenon of management. That is, while developing approaches to the management of innovation processes, we will use the scientific tools of management theory and cybernetics, based on which a sequence of seven stages is defined for the implementation of the full cycle of the management process.

1. Defining the goal (why).
2. Determining what to manage: collecting and processing information about resources and processes (what, where, when).
3. Analysis, systematization, synthesis (why).
4. Selection of the goal (decision making) (where).
5. Optimizing the stages (speed) of achieving the goal (how, when).

(Definition of tasks, methods and sequence of their execution).

6. Control (variable) influence - organization of processes for the performance of tasks and their provision with resources.
7. Control of the execution of the task (feedback - what, where, when) (maintaining the optimal speed to reach the goal).

Thus, in order to ensure the possibility of managing the innovation process, it is necessary to ensure its systematicity.

In order to determine the management potential of the innovation process, it is necessary to theoretically verify its compliance with the following necessary conditions.

Conditions for the possibility of control [14]:

1) existence of cause-and-effect relationships between system components;

2) system dynamism;

3) the presence of an influencing control parameter

it is possible to change the direction of transformations;

4) amplification property (the ability of the system to undergo significant space-time and/or energy transformations under the influence of small changes in the control parameter).

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İNNOVASİYA PROSESLƏRİNİN MODELLƏŞDİRİLMƏSİ

Xülasə

Məqalədə innovasiya prosesinin modelləri araşdırılır və hər bir nəslin mahiyyəti açıqlanır. Burada innovasiya prosesinin mərhələləri araşdırılır və innovasiya proseslərinin təsnifatı da verilir. İqtisadi artım modeli istehsalın stimullaşdırılması texnologiyasını, eləcə də cari investisiyaları nəzərə alır.

Açar sözlər: innovasiya prosesi, model, iqtisadi artım, investisiya.

Нигяр ГУСЕЙНОВА

МОДЕЛИРОВАНИЕ ИННОВАЦИОННЫХ ПРОЦЕССОВ

Резюме

В статье рассматриваются модели инновационного процесса и поясняется сущность каждого поколения. Здесь рассмотрены этапы инновационного процесса, а также дана классификация инновационных процессов. Модель экономического роста учитывает технологии стимулирования производства, а также текущие инвестиции.

Ключевые слова: инновационный процесс, модель, экономический рост, инвестиции.