

# Cascade Method for Technical Preparation of Production in Digital Technology Application

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**Abstract** — The article presents a new method for technical preparation of production in digital technology application. This method reduces risks of project, which goes over costs and deadlines. The main achievement is implementing the concept of using CALS-technologies in production technical preparation (PTP). We considered a method combining different mathematical and computer modeling approaches in order to present the best long-term strategy of production management.

**Keywords** — component; formatting; style; styling; insert

## I. INTRODUCTION

Modern industry needs to be flexible and competitive. In order to maintain its market position factories, we should always develop it for becoming better and better. Usual curve of successful production development is shown in Fig. 1.

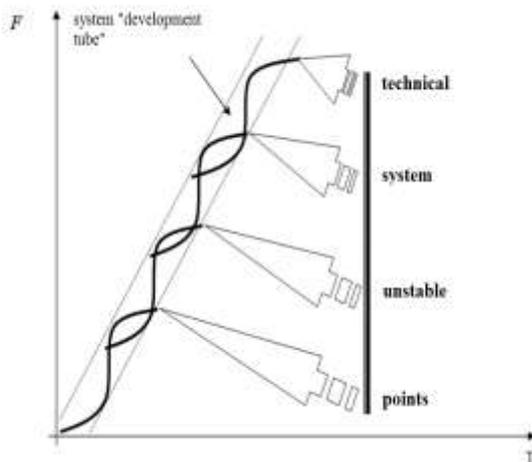


Fig. 1. S-Shaped technological systems of development curves.

Fig. 1 shows production development from the point of how production capacity is changing in time. This wave conception of production development was reviewed by author in [1]. There are big S-shaped curved and small S-

shaped curves. Both of them present production development from the capacity point of view. The small one appears when few new types of equipment are involved (usual production renewing measures). The big one appears when big production preparation project is implemented. It happens when we decide to increase producing volumes of existing product or would like to implement new one.

Production management using S-shaped curves was mentioned by Archibald in [2], but there was no information about the type of this curve. So the main science achievement of current research is new regularity for production development – curves of new technologies mastering [1]. These curves underlie and create main mathematical essence of the cascade method of the production technical preparation method. Let's consider them in general in the next chapter.

Statement of new products (innovative production) in the factory means introduction of new technologies and, respectively, the new flexible automatic transfer lines, groups of the mechatronic machine equipment, automatic sites, robotized production sites, automatic transfer lines and rotor and conveyor complexes and other complexes of the equipment providing development of technological innovations.

For production management and new technologies adoption [1, 5] as well as in research and development, it is necessary to know scientific regularities that underlie beneath formal production processes. In order to reveal named regularities let's consider two groups of production projects: the first is one during which we settle production of something new (the big projects involving a whole production department), the second is one which devoted to implementing new equipment or new technology (the small projects that involve just one technological line or something). Also we observed correlation between time and cost and correlation between time and production capacity. The first one shows us how do we implement and how we do learn new technology. We can say that new technologies implementing takes some time – transition process (fig.2). The second correlation that

Archibald mentioned is shown in figure 3. This curve can help us to maintain the project via conception Just in Time and still do not run over costs limits.

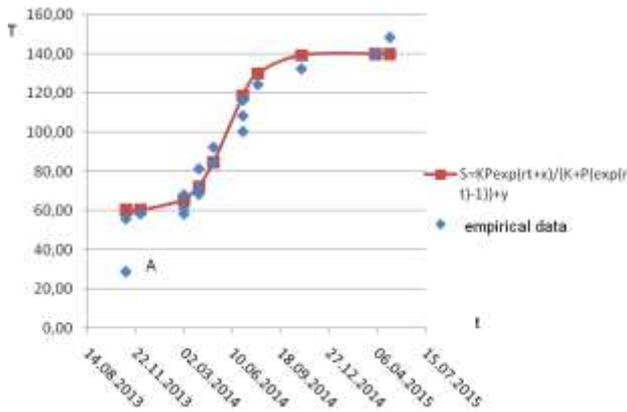


Fig. 2. The schedule of input of the mechanotronic machine equipment (the multi-purpose processing “HermleC60” center)

Note: point “A” – the special point that hasn't been connected with preparation or execution of project documentation, and designating only preparation of organizational and administrative documents.

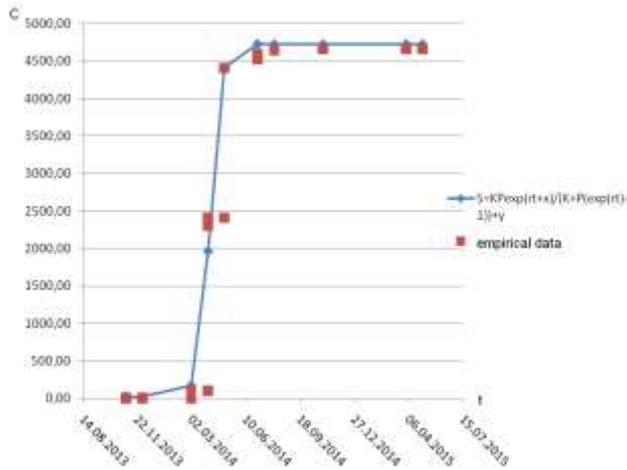


Fig. 3. The schedule of development of technologies by input of the mechanotronic machine equipment (the multi-purpose processing HermleC60 center)

Data on innovative projects of technical (technological) rearmament of production were formalized and submitted in a tabular form. Then the empirical data obtained was approximated in order to get the mathematic model of process. As a result of the made analysis it is established that in addition to [1], S-shaped dependences known from innovatics which apply in research and development, and also in analysis tasks of “diffusion of technologies” in the conditions of the decision in innovative projects of tasks of “development of new technologies” in the course of development of projects of technical (technological) rearmament of production the new type of S-shaped curves (sigmoid) in the form of the Ferkhyulst equations which in innovative design weren't applied earlier can be used.

Thus, production development from the point of view of system engineering also as well as development of new devices (designs, innovative production) can present in the form of the continuous wave process of development of technologies (fig. 1) – “curves of development of technologies” which are recommended for describing the Ferkhyulst equations.

During our research [1] it was found that these S-shaped curves can be described by algebra Verhulst differential equation solving [1, 4]:

$$S = S(t) = \frac{KP \cdot e^{r(t+x)}}{K + P \cdot e^{r(t+x)}} + y \quad (1)$$

It should be noted that small waves can be simplified down to simple line.

## II. REGULARITIES OF HIGH AND CRITICAL TECHNOLOGIES DEVELOPMENT IN PRODUCTION MANAGEMENT

The S-shaped regularities of development of the aircraft equipment (for example, fighter aircrafts) it is possible to illustrate in fig. 4. The dependences of innovative development given on this drawing generalize (unite) a set of points, each of which corresponds to this or that model of the fighter aircraft of concrete generation and concrete technology of application. It can be, for example, technologies:

- stealth technology – the production technology of the military planes providing the lowered radar, infrared, optical and acoustic visibility of aircraft;
- STOVL (Short Take-Off Vertical Landing) – in this case the plane will be able vertically to fly up or from the truncated runway and to sit down vertically.

The regression equations for these supersonic fighter aircrafts look like S-shaped curves (sigmoid).

From fig. 3 it is visible that the type of functions generally corresponds to the generalized data of the theory of the system engineering, given in fig. 1. This allows one to establish the following by means of ASSR (the automated systems scientific research) of high and critical technologies [3, 4].

The law of alternation of generations of the equipment, essentially differing with a method of performance of technology of the same appointment, claims that “for ensuring durability and/or competitiveness of technical systems of their generation replace on the basis of basic change of technologies of this generation of systems”. The explanation of the law of alternation of generations of equipment and technologies is based on the description of differences of several waves of development.

Statement on production of new products, alternation of generations of equipment have a consequence need of modernization of production of this production. This dependence can be explained with need of technological support of new qualitative properties of products and overcoming of arising disbalance of capacities of the enterprises mastering production of this equipment (products).

Thus, by means of ASSR of high and critical technologies it is possible to carry out technical justification and expediency of implementation of innovative projects of two types:

- creations and statements on production of innovative production;
- development and development of technological innovations during the solution of problems of statement on production of new equipment during development and implementation of innovative projects of technical (technological) rearmament of production.

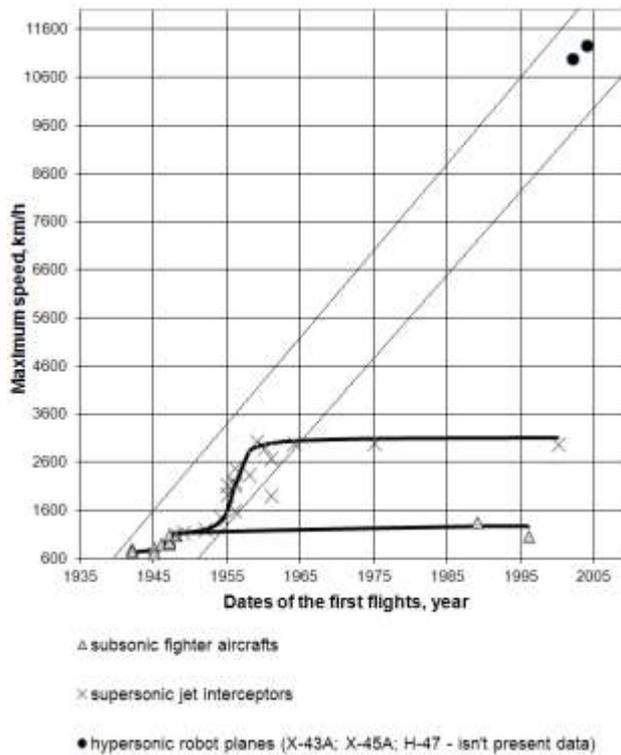


Fig. 4. The generalized S-shaped regularities of alternation of generations of jet fighter aircrafts

### III. CASCADE METHOD FOR TECHNICAL PREPARATION OF PRODUCTION IN DIGITAL TECHNOLOGY APPLICATION

Production technological preparation is a complex of methods that aimed on making factory ready to produce new goods [5]. From the [1, 4] it is known that the system of ASTPP (the automated systems of technical preparation of production) functions consists from typical blocks shown in figure 5.

Cascade method of production management observed in this work consists of 4 functional blocks that are toned in figure 5. The new cascade method of production technical preparation I project management I terms of using ASTPP is aimed at few main targets:

- reducing terms of production technical preparation,
- reducing costs of production technical preparation
- conducting production system flexibility during implementing CALS-technologies in production management.

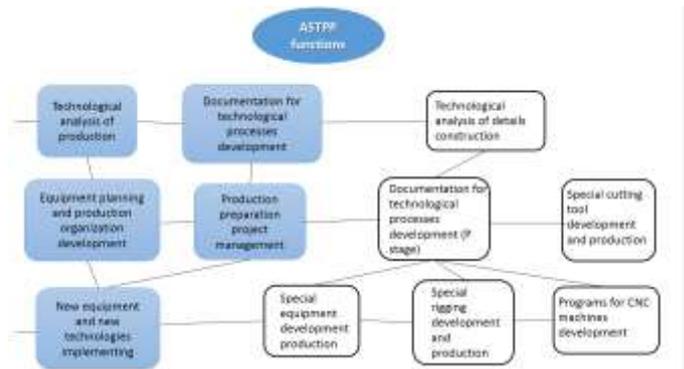


Fig. 5. Primary block-scheme of ASTPP (the automated systems of technical preparation of production) functions

The cascade method presented here should be used in factory management. It allows production management during all life cycle of the chosen department: from the moment it has been created to the moment it will be cancelled. An approach also involves conception of digital production and uses modern software. Fig. 6 presents the method essence.

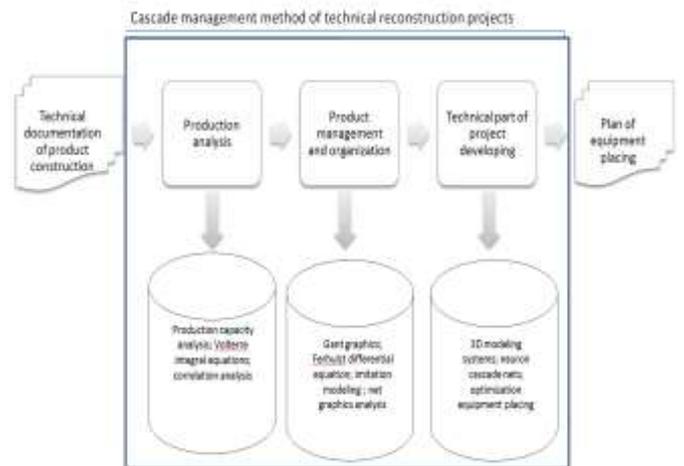


Fig. 6. Cascade method for technical preparation of production in digital technology application.

The first block represents the first step – launching time and project deadlines determination. Then we should plan the project using such programs as Project Expert or Ms Project etc. (Block 2). After that dynamic management using S-shaped curves starts (Block 3). Block 4 presents neural-based method for equipment placement optimization. Block 5 is about computer verification using Autodesk Inventor, Open CIM and Capturing motion technology room. We see that the method provides long term management strategy as we always

return to block 1 checking whether we need some reconstruction to increase production capacity. Let's breathily consider each of the blocks mentioned above.

**A. Production capacity analyzing**

As time goes on, normal production always increases producing volumes. So at last we will stuck with a problem of production capacity lack. In order to prevent unexpected production capacity deficit, we should know après when it happens. Let's take a look at Fig. 7.

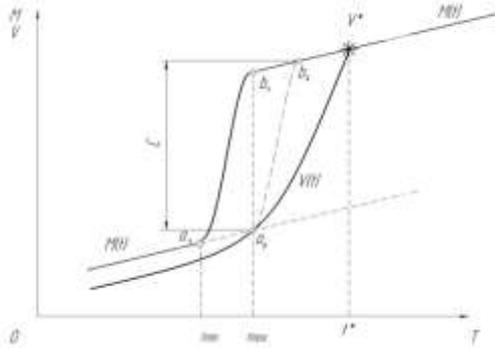


Fig. 7. Scheme for analyze and estimation financial costs on equipment in production technical preparation projects.

Fig. 5 shows analytical relations production volume changing in one factory department (or in whole factory) – V(t) and curve of production capacity growing – M(t). Production capacity growing occurs as a result of usual technology improvement activity evaluation. V\* – production value factory wants obtain till the moment t\*. Mathematical modeling problem for this process management is about two questions:

When should we launch new TPP in order to increase production capacity to be able to cover production value growing (tmin, tmax);

How much should we increase production capacity (C) in order to be able to cover production value growing.

For answering these two question cascade mathematical model of production development was supposed. This model describes production development observed by production technical preparation projects evaluation Fig. 4.

Here we have:

- First system equation shows very early terms of technical preparation project launching (tmin),
- Second system equation shows very late terms of technical preparation project launching (tmax),
- Third system equation determine the rate of factory financial spending can be gathered from internal sources (occur as a financial result of TUA). This financials can be used for factory development obtained by technical preparation projects;

- Fourth equation allows estimating that production capacity growing should be obtained by production technical preparation with the help of innovation designing.

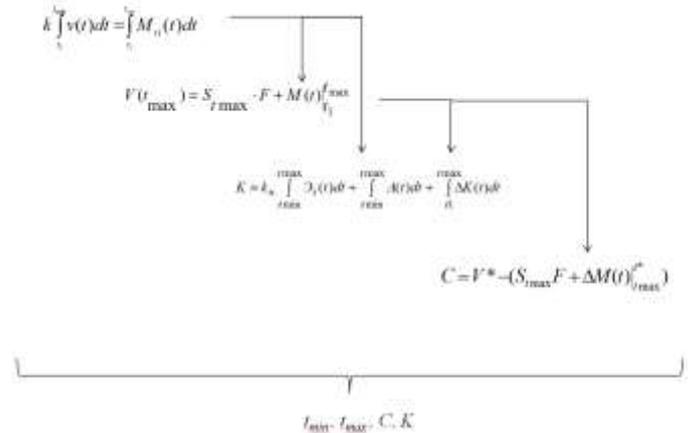


Fig. 8. Cascade mathematical model of production development.

New technologies involving management (new production capacity implementation and mastering) recommended using S-shaped regularities (Fig. 7):

(a1;β1) – S-shaped curve transient process of production preparation project implementation in terms of using financial credits;

(a1;β1) – S-shaped curve transient process of production preparation project implementation in terms of using initial financial sources (factory profit).

Inside this gap different management concepts from different financial sources can be combined and obtained.

Fig. 3 shows the curve of existing production capacity and producing volumes. Somewhere in the moment tmax the first one will cross the second one and here we will go over production capacity. But still we cannot launch some projects before tmin as tmin is a time when all equipment will be amortized. So there are two equations that can widely estimate whether we have enough capacity and when we will go out from the existing one [3, 4].

We should notice that (Fig. 7) at spots only general capacity lacks. In the case of serial and unique production, local deficit and “narrow” places can appear. These local “narrow” places can be spotted during verification using Open CIM program. Local capacity lack can be cancelled by (a) implementing new groups of equipment; (b) changing technologic processes; (c) changing order consequence.

Global capacity deficit can be solved only by PTP projects. That's why Fig. 7 determines project launching time.

**B. Project management using dynamic method based on S-shaped curves**

As at step 1 (block 1 Fig. 6) we decided to launch PTP project we should plan it (block 2) and rule it. Fig. 9 shows a general conception of that.

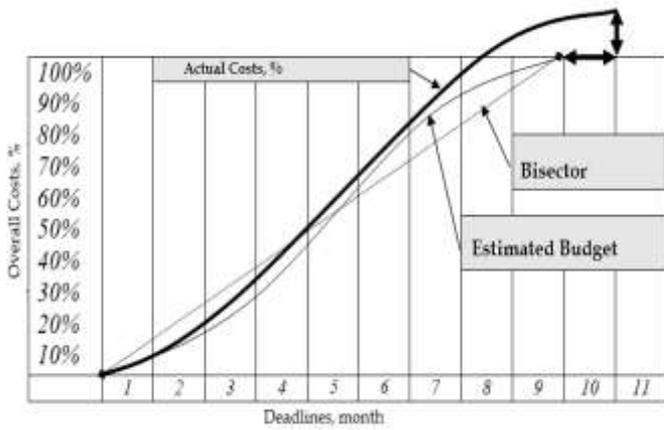


Fig. 9. Scheme for Project management using dynamic method based on S-shaped curves

In works [4] the mathematical model of the S-shaped curve in Fig. 9 is solving the algebra Verhulst differential equation [1, 4]:

$$S = S(t) = \frac{KP \cdot e^{r(t+x)}}{K + P \cdot e^{r(t+x)}} + y \quad (2)$$

#### C. Equipment placement optimization

For logistic optimization and in order to reduce production square, we should improve the technologic route and equipment placement (block 4). Details of the method were described in [1, 3, 4] here we just give a wide breath of it. The main idea of this method is firstly to classify all details on groups using Kohonin neural network and then solving Traveling Salesman Problem and the problem of optimal cutting (two classic problems of mathematical modeling). At the same time we find an optimal technological route and optimal equipment placement.

#### D. Equipment placement optimization

In order to verify whether technological and building issues during PTP project were done right, it's recommended to use 3D modelling for equipment placement drafts and different imitation modelling systems (block 5).

For building issues, verification 3D modelling technologies are recommended (Fig. 10).

In order to spot some local "narrow" places in technology of detail treatment or to spot some other wrong moments imitation modelling, using for example Open CIM is recommended. It allows visualizing the technologic process how it will be in real and in cases when we stuck with some problems to solve them immediately.

In order to prove financial project efficiency, imitation economical programs like Project Expert are recommended.

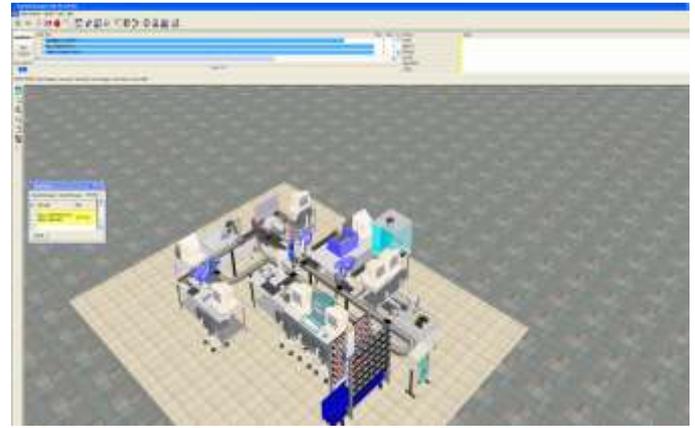


Fig. 10. Factory 3D imitation modeling using Open CIM software system

#### IV. METHOD APPROBATION

The cascade method for production technical preparation project management described above was approved at some aviation factories. It showed very good results as it took about 2 years to set up an extremely new product. Experience of using the presented method at some electronic factories allowed one to set up 80 units of unique products in 5 years in production, producing volumes growing on the same squares and with employees amount as constant.

#### V. CONCLUSION

Let us summarize the main results that were achieved:

A problem of production preparation project management was spotted.

A method for production preparation project management was proposed. This method includes cascade of other methods including imitation of 3D modelling, mathematical modelling etc.

The cascade method for production technical preparation project management was already approved in few productions in aviation and electronic sectors of the economy. It showed good results.

#### Acknowledgment

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