# Project management model of motor vehicle development with consideration of built-in quality concept requirements

*Nikita* Zhidkikh[1], *Andrey* Smolyaninov[1*], *Yury* Deniskin[2], *Violetta* Polity[2], and *Ilgiz* Mangushev[3]

[1]Voronezh State Technical University, Moscow Avenue, 14, 394000, Voronezh, Russia
[2]Moscow State University of Civil Engineering, 129337, Yaroslavskoe shosse, 26, Moscow, Russia
[3]Moscow Aviation Institute (National Research University), Volokolamskoe shosse, 4, 125993, Moscow, Russia

**Abstract.** Problem of long timeframes of new car model development cycle due to excessive testing process of numerous vehicle prototypes is specified. Positive example of solving the problem using digital twin, computer modelling and virtual testing technologies in Formula 1 is given. Positive effect of virtual verification and validation during the development process on built-in product quality and development cycle time reduction is indicated. Existing project management V-models in automotive and information technology industries are reviewed and analyzed. State standards and methodologies of project management, lean manufacturing and digital twin development are reviewed. The improvements based on project life cycle, project management processes and product life cycle are enumerated and explained. Improved V-shaped project management model is described and visualized. The proposed model positive effects are described: it allows to increase the level of built-in vehicle quality, shorten its development cycle timeframes while providing the connection between project management and product development processes. **Keywords:** car, prototype, planned quality, verification, validation, mathematical modelling, virtual simulation, digital twin, V-model, project management

## 1 Introduction

The release of a new car model is a project implemented under time and resource constraints. Public road motor vehicle development cycle and its further entry into the consumer market takes an average of 2 to 5 years. At the same time, the total mileage of several dozen of its prototypes can reach several million test kilometers around the world [1].

The goal of car manufacturers, like any other industrial enterprise, is to make and increase profits. This can be achieved by increasing sales of new cars. However, the current timeframes for the release of new models are too wide. Although it depends on the speed of the new product entering the market whether the car company will gain a competitive advantage by capturing larger segments of the automotive market. Therefore, it is extremely

* Corresponding author: u00781@vgasu.vrn.ru

important to ensure the possibility of reducing and meeting the deadlines for the implementation of projects for the development of new car models [2].

Often the reason for the long development time of new vehicles is a long physical testing cycle of several tens, and sometimes hundreds of prototypes. They are carried out all over the world - both in normal and especially extreme operating conditions to ensure its quality and durability. Therefore, the timing of the implementation of automotive projects can be reduced by optimizing testing programs [3].

A typical example of successfully implemented projects, the result of which is the creation of a new car in a short time with a minimum amount of physical testing, is the development of cars for the FIA Formula One World Championship. Its Sporting Regulations allow to carry out physical Testing of Current Cars (TCC) only during test days sanctioned by the championship governing body – FIA (Federation Internationale de l'Automobile) – which take place only a few times during the championship season. There is also a limitation for Wind Tunnel Testing time for F1 vehicle scale mockup models [4]. These restrictions are designed to reduce the expenditures of racing teams and level the backlog of private teams from the largest automotive manufacturers motorsport divisions. Therefore, the Formula 1 teams have implemented the technologies of creating digital twins of cars, which include the creation of digital models of products and their virtual simulation [5].

In the civil automotive industry, it is also possible to replace physical tests with virtual ones everywhere using digital twin technologies (with the exception of procedures that strictly require physical testing, such as crash tests). They will allow to perform virtual verification and validation to assess the compliance with input requirements already at the design stage. This will increase the level of built-in quality, i.e., prevent the release of low-quality products, while reducing the cost and timeframes of developing prototypes of cars [6].

However, the effectiveness of digital twin technologies is ensured not only through virtual testing at the design stage. They are used at all stages of the product life cycle and involve the use of digital twin software and technology platforms. These platforms typically include not only product development tools, but also project management tools.

## 2 Goal of the work

Thus, the purpose of this work is to develop a project management model for the creation of new car models, which would reduce and allow to strictly comply with the deadlines for product development through the use of digital twin technologies. This model will have to take into account the need for virtual vehicle testing to ensure a high level of built-in quality without resorting to optional physical tests.

The main task in this case is the analysis of existing project management models based on the widespread verification and validation of developed products [7]. At the same time, it is proposed to use generally accepted state standards and international methods:

- in the field of project management - GOST R 54869-2011, 7th edition of the Project Management Body Of Knowledge (PMBOK) and the Deming-Shewhart PDCA Cycle (Plan-Do-Check-Act);
- in the field of lean manufacturing - GOST R ISO 9000-2015 and GOST R 57522-2017;
- in the field of digital twins of products - GOST R 57700.37-2021.

# 3 Models and Methods

## 3.1 Magna Steyr Automotive Project Management V-Model

The Austrian contract vehicle manufacturing Magna Steyr AG & Co KG company has developed a V-model for the automotive projects execution (Fig. 1).

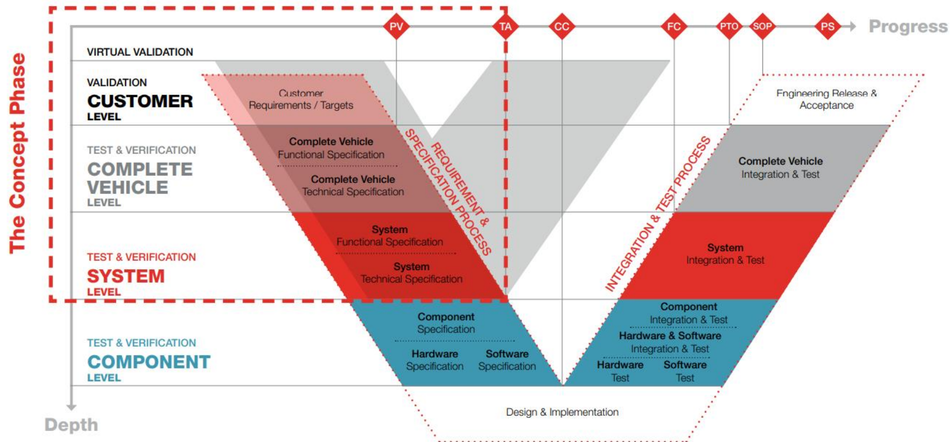


**Fig. 1.** Automotive Project Management V-model (Magna Steyr AG & Co KG).

Magna Steyr model runs from left to right along the horizontal Progress axis over time [8]. The left branch of the graphic characterizes the level of depth of the gradual development of functional and technical requirements and specifications, as well as for future testing programs of the product, its systems and components, moving from top to bottom through 4 automotive vision levels:

1. "Customer" - the level of a product vision formation and the consumer requirements definition;

2. "Complete Vehicle" - the level of a complete product, which must meet the requirements of the "Consumer" level;

3. "System" - decomposition of the "Complete Vehicle" level. This level can be decomposed multiple times depending on the applied product design methodology;

4. "Component" - decomposition of the "System" level, describing the final minimum units of the product.

At the same time, the stages of determining the requirements of potential consumers, the formation of specifications for the entire vehicle and its individual systems are combined into "The Concept Phase", within which virtual validation of compliance with the input requirements can be carried out. However, this procedure is not obligatory within the considered model [9].

Then the transition to the left branch is carried out along the lower segment of the diagram, which characterizes the transition of the product from the state of an engineering project to the state of a physical object, which includes the processes of designing, manufacturing and purchasing individual components.

The movement along the left branch describes the sequence of testing and integration of components, systems and the entire product in accordance with the programs developed during the movement along the right branch of the graphic. This process ends with the acceptance of the product and the approval of the launch of its mass production [10].

Also, the key milestones of the project are marked on the graphic:

• PV – Product Vision;
• TA – Target Approval;
• CC – Concept Confirmation;
• FC – Functional Confirmation;
• PTO – Production Try-Out;
• SOP – Start of Production;
• SP – Process Stability.

It should be noted that the V-model of Magna Steyr is based on the V-model of information systems development created in Germany and the USA in the 1980s (Fig. 2), which is based on the principle of ubiquitous verification and validation [11]. Therefore, the Magna Steyr V-model has its main disadvantages:

• This model includes only 3 of the 6 phases of PMBOK project management: building of the project deliverable, its testing and deployment [6]. At the same time, there are no phases of feasibility, project design and closing;

• The Magna Steyr model does not follow the Deming-Shewhart Cycle (PDCA) because it does not reflect the project planning process.

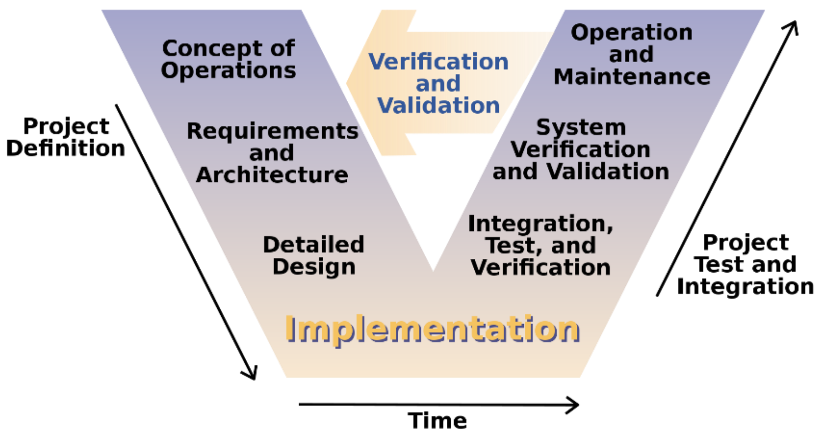


**Fig. 2.** V-model of information systems development.

### 3.2 Modern V-Model XT Software Development

The V-model of IS development has been improved in accordance with the needs of projects in the field of information technology. Its updated version (Fig. 3.) - V-model XT (eXtreme Tailoring) - approved at the federal level in Germany as a recommended model for managing software development projects [12].

This model includes not only system development processes, but also project management processes. The processes of interaction between the customer and the contractor are also provided. At the same time, iteration is allowed - repeated repetition of the system development cycle, taking into account the results of monitoring the project implementation.

A significant difference between the XT V-model and the classical V-model is the purpose of the circuit elements - they do not describe processes, but decision-making control points, after passing which the course of the project can be influenced. Such impacts can be provided by both the customer and the contractor [13].

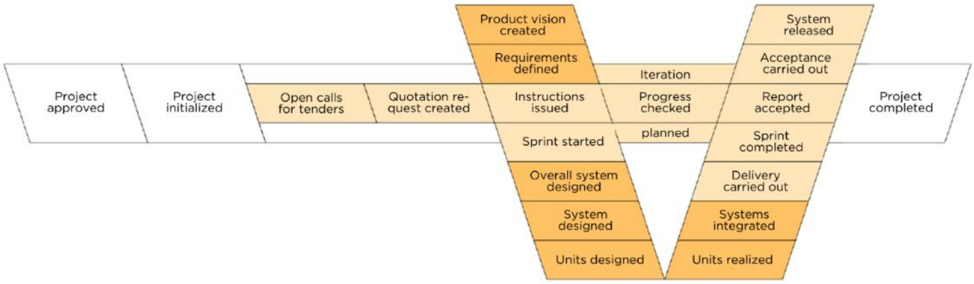


**Fig. 3.** Typical diagram of the V-model XT of software development.

White color indicates the milestones inherent in each project - approval, launch and completion. Light orange color highlights the control points of the project owner related to the conclusion of contracts and control of the project implementation. The dark orange areas of the diagram refer to the contractor directly involved in the development of the IT product, and include the phases from the development of the general concept to integration into the information system [14].

The V-model XT still does not take into account the project planning process, however, it focuses on documented procedures that affect the official relationship between the customer and the contractor - the announcement of a tender, the conclusion of contracts, the approval of reports, etc. Thus, the V-model XT is suitable for projects that require a guaranteed demand for the product being developed. However, in the automotive industry, the decision to launch a project to develop new car models is not made on the basis of a commercial proposal, but on the results of a market analysis, taking risks into account, which include, among other things, the lack of demand for the product [15].

### 3.3 Analysis results

Analysis of the above V-models of project management revealed a number of advantages and disadvantages of each scheme, presented in Table. 1.

**Table 1.** Results of the analysis of V-models of project management.

| Life cycle model | Advantages | Disadvantages |
|---|---|---|
| V-model Magna Steyr | • Provides verification and validation at all stages of product development<br>• Takes industry specifics into account<br>• Highlights both milestones and project processes<br>• Provides virtual validation of the product and its systems | • Does not include activities of launching, planning and closing of the project<br>• Does not oblige to conduct virtual validation of the product and its systems<br>• Provides late testing of the finished product |
| V-model XT | • Provides adaptation to a specific project<br>• Provides project launch and completion activities<br>• Allows you to make changes to the product based on the results of control<br>• Reflects decision milestones | • Tailored for projects that require a specific customer<br>• Involves a large number of documented procedures<br>• Does not reflect project implementation processes, but only milestones |

### 3.4 Proposal of the modified V-model

When refining existing V-models for managing automotive projects, the following factors will need to be taken into account:

- Previously presented results of the analysis of V-models of project management;
- Phases of the project life cycle in accordance with the Project Management Body of Knowledge (PMBOK) [6]:
  - Feasibility;
  - Design;
  - Build;
  - Test;
  - Deploy;
  - Close.
- A set of project management processes in accordance with GOST R 54869-2011 for their integration into the digital twin of the product being developed [16]:
  - Inititation processes;
  - Planning processes;
  - Execution organization processes;
  - Execution control processes;
  - Closing processes.
- The need to integrate procedures for virtual testing of mathematical and computer models in the product development process in order to reduce the cost and reduce the time for creating its prototypes and prototypes [17];
- Phases of product life cycle in mechanical engineering.

## 4 Study and results

Thus, the V-shaped project management model for the development of new car models was finalized and formed (Fig. 4). It retains the main features of the Magna Steyr V-model, namely, the division into levels according to the depth of study with the addition of the "Project" level, as well as control points. From the V-model XT, the principle of iteration in making changes and the principle of end-to-end implementation of project management processes was borrowed [18].

Project initiation begins with the initiation processes (marked in green), during which the characteristics of the project, such as its goals and products, as well as the customer, are determined. In the case of the development of a new civilian car, instead of the customer, the target audience of the product is indicated, which is determined as a result of marketing research that proves the potential viability of the project. After that, the project can be considered open.

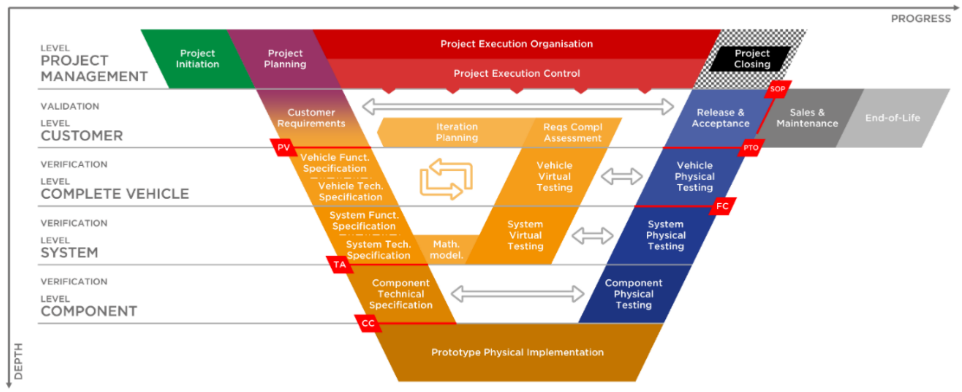


**Fig. 4.** Proposed V-model.

Then the project planning takes place (indicated in purple), which includes the determination of the product characteristics required by the potential consumer, i.e., in fact, the development of initial technical specifications. This stage, being part of the planning process, is the first stage of the development of a new product, since it allows you to form a vision for the product (red PV milestone). Planning also covers the development of the project schedule, budgeting, project team formation, procurement planning, risk analysis and response development, communication and management changes of the project [19].

Then the project enters the product design phase (highlighted in orange-brown colors), at the same time, the processes for organizing the execution and control of project execution (highlighted in dark red colors) are launched, carried out until the completion of the project. After the completion of the development of the technical description of all systems, the movement along the left branch of the scheme moves to the right in order to perform mathematical modeling of the systems. The systems are then tested individually as well as together, simulating the operation of the entire vehicle. These tests make it possible to assess compliance with the requirements of potential consumers without resorting to the production of prototypes, i.e., to carry out virtual verification and validation. This movement through the internal V-model provides iteration (orange arrows), which makes it possible to make multiple changes in the concept of the entire product and its systems, which significantly saves time on re-production of prototypes [20].

As soon as the virtual tests show compliance with the input requirements, the milestone of TA is reached, and the development of a description of the individual components begins. This also implies the processes of virtual verification of computer models, which have become widespread today. Upon reaching the CC milestone, the project moves to the stage of physical implementation through the production of prototypes of the product. It should be noted that the previously conducted virtual tests do not relieve the manufacturer of the need for their production, but they can significantly reduce their total number and the volume of further physical tests [21].

Prototypes produced move into the product testing phase. The movement of the model is now carried out from the bottom up, as in other existing V-models. However, verification of systems and the entire product is recommended not only in comparison with previously developed functional and technical specifications, but also with mathematical models testing. The results of their virtual tests reflect a range of performance characteristics that can be compared to the results of physical tests through two-way links between the digital model and the prototype. This ensures the implementation of the principle of a digital twin at the stage of physical testing. At the same time, successful verification of all systems brings us to the FC milestone, and the entire vehicle - to PTO. The tests are completed with the acceptance of an pilot batch of vehicles, which is being validated for compliance with the input requirements. Acceptance is also one of the processes for formally completing a project to develop a new car model [22].

Completion of the development project occurs in parallel with the launch of mass production (SOP milestone). However, this only ends the development of a product, the development cycle of which was originally necessary to shorten. The life cycle of a car does not end there, because it enters the stage of sales and after-sales service. At the same time, it is possible to revise the design documentation for the car and launch a recall campaign if consumers detect frequent failures of any components. However, multiple virtual and final physical tests are designed to rule this out.

During operation by end users, vehicles can accumulate and send the necessary data to the manufacturer, providing two-way communications with the digital model of the car. This allows the digital twin to be analyzed over the long life cycle of the product and improve the built-in quality of subsequent vehicle generations [23].

## 5 Conclusions

The result of this work is an updated V-shaped project management model for the development of new car models based on the provisions of state standards in the areas of project management, lean manufacturing and digital twins, as well as the results of the analysis of existing V-models. The modified model takes into account the features of digital twin technologies, the phases of the product life cycle, as well as project management processes. Combining them within a single management model allows for a reduction in the product development cycle, both by conducting virtual tests at the development stage, and by ensuring the relationship of project management processes with all the processes of creating new cars, which has a beneficial effect on the level of built-in quality of products.

## References

1. E.N. Ermolaeva, A.A. Kadykova, Russian Engineering Research **42(7)**, 748-752 (2022) doi:10.3103/S1068798X22070085
2. E. Ermolaeva, T. Karapetyan, E. Surkova et al, Transportation Research Procedia **63**, 1608-1620 (2022) doi:10.1016/j.trpro.2022.06.175
3. I. Artamonov, N. Danilochkina, I. Pocebneva, K. Karmokova, Transportation Research Procedia 63, 1668-1673 (2022) doi:10.1016/j.trpro.2022.06.180
4. S. Serebryansky, B. Safoklov, I. Pocebneva, V. Lepeshkin, Improving the efficiency of production processes of enterprises of the aviation (2022) industry doi:10.1007/978-3-030-80946-1_91
5. I. Novikov, A. Deniskina, V. Abyzov, O. Papelniuk, Transportation Research Procedia **63**, 1601-1607 (2022) doi:10.1016/j.trpro.2022.06.174
6. D. Golovin, S. Belyaeva, N. Zhidkikh, A. Misailov, E3S Web Conf. **363**, 04006 (2022) DOI: 10.1051/e3sconf/202236304006.
7. M. Akhmatova, A. Deniskina, D. Akhmatova et al, Transportation Research Procedia **63**, 1512-1520 (2022) doi:10.1016/j.trpro.2022.06.163
8. A.R. Deniskina, I.V. Pocebneva, A.V. Smolyaninov, Proceedings - 2021 International Russian Automation Conference, RusAutoCon 2021, 17-22 (2021) doi:10.1109/RusAutoCon52004.2021.9537333
9. B. Safoklov, D. Prokopenko, Y. Deniskin, M. Kostyshak, Transportation Research Procedia **63**, 1534-1543 (2022) doi:10.1016/j.trpro.2022.06.165

10. Y. Deniskin, A. Deniskina, I. Pocebneva, S. Revunova, E3S Web of Conferences **164** (2020) doi:10.1051/e3sconf/202016410042
11. E.N. Ermolaeva, A.A. Kadykova, Russian Engineering Research **42(4)**, 416-419 (2022) doi:10.3103/S1068798X22040062
12. V.I. Bekhmetyev, V.A. Tereshonkov, V. Lepeshkin, VERTICAL CAD in the design of efficient technologies for making aircraft glider parts (2022) doi:10.1007/978-3-030-94202-1_28
13. V. Subramanian, W.J.G.M. Peijnenburg, M.G. Vijver et al, Chemosphere **311** (2023) doi:10.1016/j.chemosphere.2022.137080
14. B. Bonino, F. Giannini, M. Monti et al, Geometric analysis of product CAD models to support design for assembly (2023) doi:10.1007/978-3-031-15928-2_61
15. C. Qiu, J. Tan, Z. Liu et al, Chinese Journal of Mechanical Engineering (English Edition) **35(1)** (2022) doi:10.1186/s10033-022-00779-0
16. M. Moreno-Benito, K.T. Lee, D. Kaydanov et al, International Journal of Pharmaceutics **628** (2022) doi:10.1016/j.ijpharm.2022.122336
17. B. Safoklov, D. Prokopenko, Y. Deniskin, M. Kostyshak, Transportation Research Procedia **63**, 1534-1543 (2022) doi:10.1016/j.trpro.2022.06.165
18. S. Xing, Z. Jiang, X. Zhang, Y. Wang, Mathematics **10(14)** (2022) doi:10.3390/math10142477
19. L. Zhang, R. Tan, Q. Peng et al, Applied Sciences (Switzerland) **12(13)** (2022) doi:10.3390/app12136358
20. Y. Lei, S. Vyas, S. Gupta, M. Shabaz, International Journal of System Assurance Engineering and Management **13**, 305-311 (2022) doi:10.1007/s13198-021-01404-4
21. M.F. Aguiar, J.A. Mesa, D. Jugend, M.A.P. Pinheiro, P.D.C. Fiorini, Management of Environmental Quality: An International Journal **33(2)**, 300-329 (2022) doi:10.1108/MEQ-06-2021-0125
22. A. Barabanov, S. Serebryansky, Proceedings of 2020 13th International Conference Management of Large-Scale System Development, MLSD 2020 (2020) doi:10.1109/MLSD49919.2020.9247777
23. D.Y. Strelets, S.A. Serebryansky, M.V. Shkurin, Proceedings of 2020 13th International Conference Management of Large-Scale System Development, MLSD 2020 (2020) doi:10.1109/MLSD49919.2020.9247749