APPLICATION OF PROJECT MANAGEMENT: LEAN TECHNOLOGIES AND SAVING MANUFACTURING (ASPECTS OF MANAGEMENT AND PUBLIC ADMINISTRATION)

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Summary
Successfully adapting to digital and customer-oriented transformation, the concept of lean manufacturing professes the philosophy of creating greater benefit while minimizing losses. These losses are operations that do not add value in the production process to ensure the efficiency, flexibility, and profitability of projects. In the context of broad automation and digitalization of all sectors of the economy, mechanisms for combining automation technologies and lean production are becoming available. Moreover, when it comes to the efficient use of financial, human, or material resources, it is clear that the use of Industry 4.0 technologies can be an effective tool for achieving the goals of lean production, as many of them pursue the same goal.
In this context, this article aims to study the effectiveness of the implementation of project management concepts at the global level and identify the main factors influencing its effectiveness to ensure the achievement of lean production through LEAN technologies and Industry 4.0 technologies. To achieve this goal, several statistical indicators were selected and several statistical methods of analysis were used: pairwise correlation, regression analysis, methods of comparison, synthesis, and generalization. Statistical analysis was conducted according to a survey conducted by the Project Management Institute (PMI) in 2020. An economic-mathematical model of dependence of project effectiveness in different regions of the world on the level of implementation of project management approaches is built, which shows that the increase in project effectiveness by 85% is due to financial losses, technical training, and consumer orientation. These results allow project managers to develop appropriate strategies to improve project management approaches at all levels. It is established that LEAN technologies and technologies of Industry 4.0 have several tools that have a positive effect on minimizing losses following the concept of lean production. Besides, given that the technology of Industry 4.0 is focused on the automation of Lean Production technology, a mechanism for the introduction of lean production using these technologies and methods.

Keywords: *project management, LEAN-technologies, Industry 4.0, lean production, global level, regression model, losses.*

1. Introduction

Lean manufacturing is a multifaceted production approach that includes a variety of tools aimed at identifying value creation processes for the consumer (Sanders et al., 2016 [1]), ensuring maximum customer satisfaction while minimizing losses and, consequently, increasing profitability. Given the constant development of the project approach and its improvement, projects are becoming more complex, changing requirements for both project managers and information and communication infrastructure.

From a technological point of view, lean production is not possible without full or partial automation of processes, because with the help of LEAN technologies, the complexity of production systems must be reduced. However, total automation does not always increase productivity and can complicate the system. The integration of Industry 4.0 and LEAN technologies is already underway and is referred to as Lean Automation. Lean Automation aims for higher variability and shorter information flow to meet future market needs. Contrary to popular belief, Lean Manufacturing does not preclude automation, but on the contrary, a combination of Industry 4.0 and LEAN technologies can provide a synergy effect.

Following the principles of autonomy of lean production, operations that are repeated over time and add value should be automated (Bilberg, 2003 [2]). Today, there is the concept of "Low-Cost Intelligent Automation" (LCIA), which prefers standardized and automated, flexible and cost-effective solutions. Its disadvantage is that the main focus here is on mechanical and electrical systems and does not consider the information and communication

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technologies that are so important for project management. Lean Production and Industry 4.0 technologies have many common features: first, they are most often used in decentralized structures of small systems, and secondly - they are aimed at small, easy to integrate modules with a low level of complexity (Kolberg et al., 2016 [3]), which meets the needs of the design approach.

It should be emphasized that Industry 4.0 technologies make it possible to directly link technological, digital data, with physical, i.e. machines, production equipment, and even with humans, thus playing the role of integrating technology, skills, and physical production process, ensuring maximum effect with minimal losses, which is the basis of the philosophy of lean production.

2. Literature review

In the process of industrialization, the introduction of the LEAN concept is a key factor in the development of new products, because here the main attention is paid to eliminating possible losses in the production process with an emphasis on meeting consumer needs and taking into account the analysis of economic, operational and technical feasibility (Pfaffenzeller, et al., 2015 [4]): the ability of organizations to support costs and benefit from the project; competencies and ability of project staff to avoid losses and respond quickly to customer needs; provision of organizations with modern equipment and the ability of staff to master new production technologies related to information and communication technologies.

(Welo & Ringen, 2015 [5]) identify six main components of lean manufacturing with different sub-characteristics that meet the LEAN concept and are used to develop new products, namely: consumer value, market research, continuous improvement strategies, stabilization and standardization, and LEAN culture improvement. There are several studies related to the introduction of lean production in projects of different types of the organizational structure of enterprises (Caldera, et al., 2017 [6]) (Alkhoraif, et al., 2019 [7]). The application of lean manufacturing in various sectors of the economy is also quite widely studied, for example, in civil engineering (Tezel et al., 2018 [8]), chemical industry (Jilcha & Kitaw, 2015[9]), textile (Manfredsson, 2016 [10]), food (Vlachos, 2015 [11]), in agricultural production (Vostriakova et al., 2021 [12]), in the field of health care (Kovacevic et al., 2016 [13]), energetics (Sree Lakshmi et al., 2020) [14] etc. Examples of the implementation of LEAN technology are revealed in case studies of European countries, (Möldner, et al., 2020 [15]), (Secchi & Camuffo, 2019 [16]), (Dong, et al., 2019 [17]), Asian countries, (Pipan, 2018 [18]), (Brocal, et al., 2018 [19]), USA, (Ramos, et al., 2018 [20]), (Bekdik, et al., 2016 [21]), and African countries (Lin & Omoju, 2015 [22]).

Along with this, there is quite a lot of research that considers the concept of Industry 4.0 as helpful in improving lean production approaches (Prinz et al. 2018 [23]), (Dombrowski & Richter, 2018 [24]), (Hartmann et al. 2018 [25]), (Hoellthaler et al. 2018 [26]).

Wagner et al. (2017 [27]) and Pokorni et al. (2017 [28]) note that lean production processes can be consolidated using Industry 4.0 technologies. Rüttimann & Stöckli (2016 [29]) consider the introduction of Industry 4.0 technologies as a possible increase in the flexibility of lean production, or improvement of its elements (Kolberg & Zühlke, 2015 [30]).

This article aims to study the effectiveness of the implementation of project management concepts at the global level and identify the main factors influencing its effectiveness to achieve the goals of lean production using LEAN technologies and technologies of Industry 4.0.

To achieve this goal it is necessary to perform the following tasks:

Analyze the effectiveness of the implementation of project management concepts in the economy at the global level;

Conduct a correlation-regression analysis of the effectiveness of projects at the global level and identify the main factors of influence;

Develop a mechanism for implementing lean production using LEAN technologies and Industry 4.0 technologies.

3. Methodology

To conduct this study in the process of substantiation of theoretical and methodological bases of analysis of project management in general and lean production in particular, general scientific methods of economic analysis were used: method of comparison in assessing the level of project management of the studied regions and the world and industry; pair correlation and regression analysis - in determining the relationships between the studied factors and their impact on the resulting indicator, methods of generalization, systematization, synthesis, the study of phenomena and processes in their development and relationships, comparisons, analogies, classification, grouping, etc.

The study is based on original marketing research conducted at the global level of PMI in 2020, which reflects the views of project managers and the results of programs and projects, as well as includes the analysis of supporting data. The 2020 survey reflects the views and conclusions of 3,060 project professionals, 358 senior executives, and 554 project management directors in a variety of industries, including information technology (IT), financial services, public sector, manufacturing, energy, construction, healthcare, and telecommunications. Respondents cover the

global dimension, including North America, Europe, the Middle East, Africa, ASEAN (Association of Southeast Asian Nations), China, India, Latin America, and the Caribbean. The data are presented by industry and region in comparison with the global average.

Based on the correlation analysis, the main factors that have a direct impact on the effectiveness of projects at the level of the studied groups of countries are selected. The list of studied indicators is given in Table 1.

Table 1 Input system of indicators for correlation-regression analysis of project management implementation at the global level

Group of indicators	Designation	Characterization
Project effectiveness (%)	Y	Percentage of projects that have achieved the set goals and business intentions
Losses, (% of 1 billion invested in the project, USD)	X1	Overspending, inefficient use of funds
Level of project management implementation (%)	X2	Organizations with a high level of experience in project portfolio management
	X3	Organizations with ongoing staff training on project management tools and methods
	X4	Organizations with career opportunities in project or program management
	X5	Organizations where the development of technical skills is a priority
	X6	Organizations where leadership development is a priority
	X7	Organizations where business skills development is a priority
	X8	Organizations where the development of digital skills is a priority
	X9	Organizations where the development of customer focus skills is a priority

Source: formed by the author on the basis (PMI, 2020 [31])

4. Results

In today's dynamic environment, many organizations use projects to generate value for the consumer, increase competitiveness and manage the enterprise in conditions of uncertainty. Due to globalization, the development of innovation, and rapid and unpredictable changes in global markets, organizations are increasingly turning to process management to project management to enhance their competitive advantage. The percentage of project management implementation in the activities of enterprises of different sectors of the economy is shown in Figure 1.

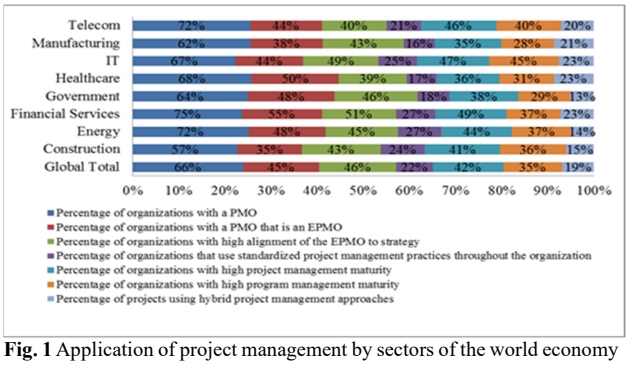

Fig. 1 Application of project management by sectors of the world economy as of 2019* * **Source**: formed by the author according to PMI, 2020

* Note PMO - project management office; EMPO - project management office at enterprises.

Organizational support of project management is constantly evolving along with new technologies and approaches to planning, budgeting, resource provision, data analysis, tracking time for project implementation. It should be noted that hybrid management methods are becoming increasingly popular, displacing the standardized flexible methods used traditionally. The implementation rate in the project management development strategy of the establishment of the Enterprise Project Management Office (EPMO), which differs from the traditional PMO in that it works at the strategic level in cooperation with managers to ensure project management not only within an individual enterprise but also within industry level.

The main trends in the development of organizational features of project management according to Fig. 2., which are the most common at the global level include investment in technology (53%), certification of specialists (51%), the development of a culture of perception of organizational change (53%), attracting outside investment sponsors (61%) and the priority of project management as a core value (69%). While the implementation of LEAN technologies and culture of value creation is observed in only 41 and 46 percent of organizations, respectively.

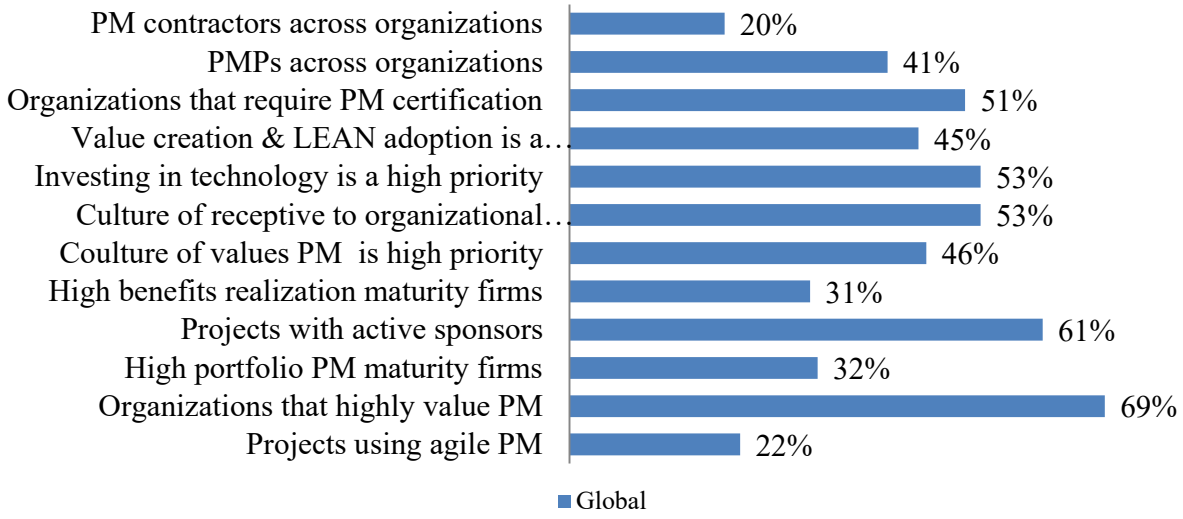

Fig.2. Organizational features of project management implementation
* **Source:** formed by the author according to PMI, 2020
Note * PM - Project Management; PMP - Project Management Professional

As can be seen from Fig. 2. The popularity of project management at the global level is growing; projects are also becoming more complex. The scope of project management is changing and is changing rapidly. New tools, technologies, and mechanisms are destroying traditional approaches and beliefs. To be ready to adapt to rapid changes in the external environment, managers must have reliable analytical information on the percentage of project success (Fig. 3 and 4), the main causes of failed projects, factors affecting the effectiveness of projects, and the main tools and methods of project management that best meet the needs of an individual organization.

According to Fig. 3. The most successful areas of application of project management, i.e. with a high (above the global average of 69%) percentage of projects that meet the goals and expectations of the organization include energy, finance, IT, and telecommunications. However, it should be noted that all projects in these areas were implemented with time delays and budget deviations, except for the areas of IT and telecommunications, which show high compliance with deadlines and allocations.

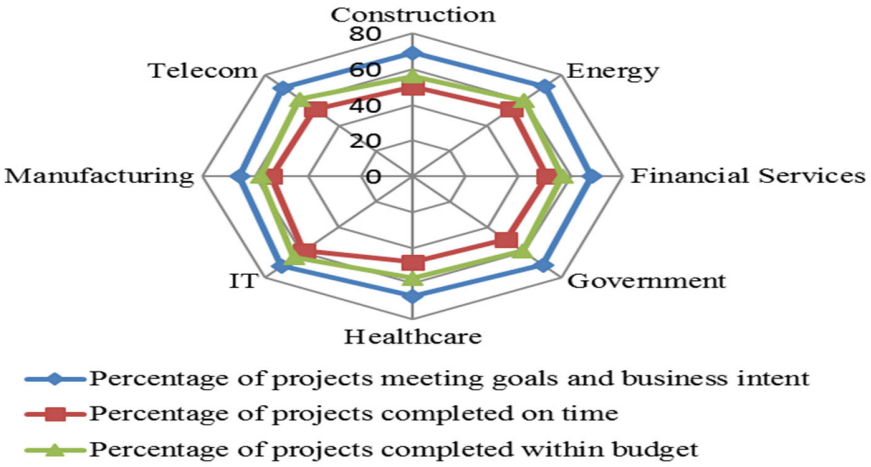

Fig. 3. Effectiveness of projects by sectors of the economy in the global dimension, 2020
Source: formed by the author according to PMI, 2020

The inefficiency of project implementation directly depends on the efficient use of resources, especially financial. Globally, companies are losing $ 114 million for every $ 1 billion spent on projects and programs due to low project efficiency. Compared to the global average, Australia, Brazil, Canada, Europe, Latin America, North America, and the United Kingdom use the least efficiently. It is inefficient to spend from 123 to 133 million dollars for every billion spent (Fig. 5).

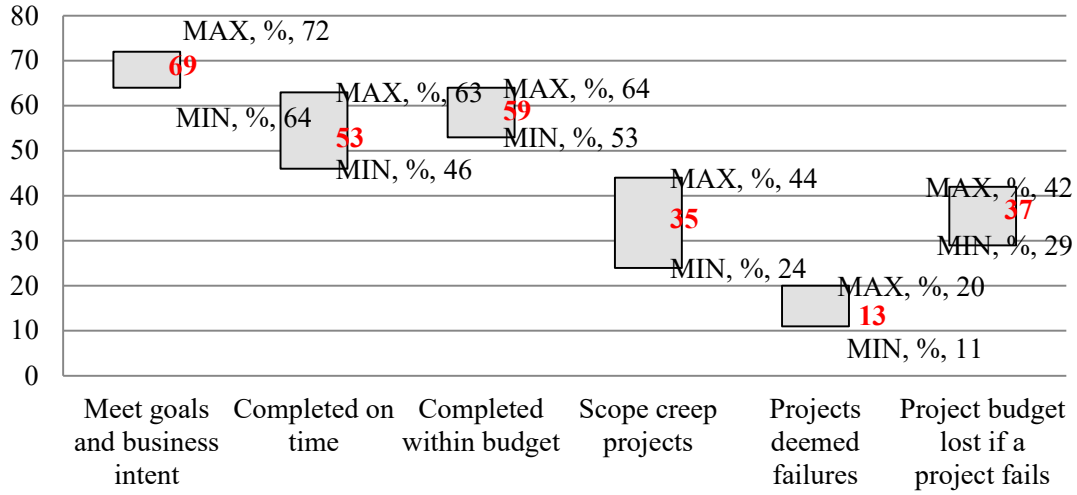

Fig. 4. The percentage ratio of project performance by groups of studied countries, 2020

* **Source:** formed by the author according to PMI, 2020

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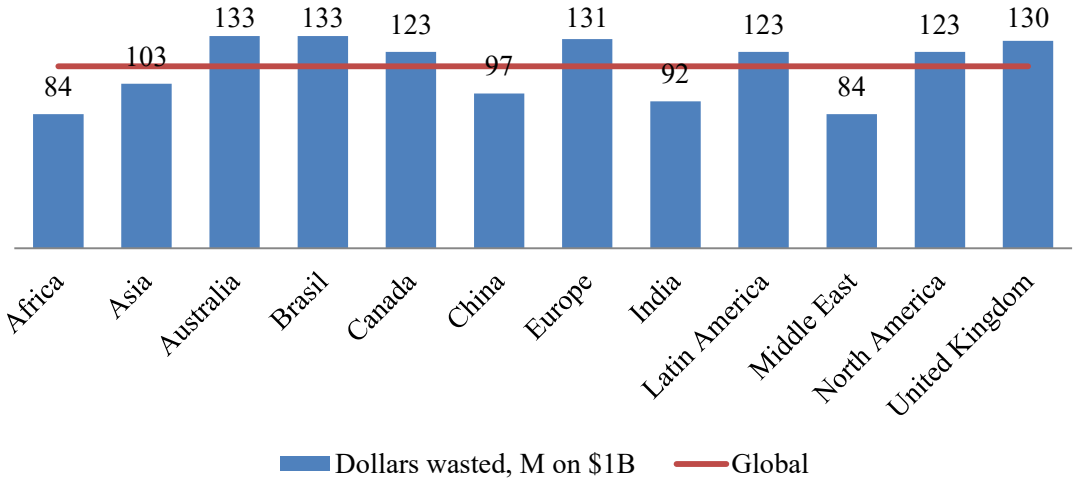

Fig. 5. Financial losses of project management of the studied groups of countries, 2020

In the course of our research, we tried to find an answer to the question about the factors that affect the effectiveness of project management the most. Today, in the conditions of the unstable economic situation in the world, a necessary precondition for the development of the management strategy of the organization is to make clear calculations that would allow it to be effectively adjusted to the best world experience.

To take into account all available factors (organizational, managerial, and human resources) that affect the level of project effectiveness, we conducted a correlation analysis of several indicators to determine the density between the performance trait and factor values to build an economic-mathematical model. To this end, based on a survey conducted by PMI and a correlation analysis of the relationship between indicators of the level of project management implementation in the study regions, we formed a sample of factors that have the greatest impact on the effectiveness of projects.

The analysis of the impact of factors was conducted based on data from the PMI (2020) study, grouped in 12 regions by the percentage of project management implementation in 2020.

The interaction of project performance (Y) with the factor characteristics of the level of project management implementation (X1, X2….Xn) (Table 1) is described using the linear multifactor regression equation.

The percentage of projects that achieved the set goals and business intentions was chosen as the result indicator (Y), and the following indicators were chosen as factor values:

X1 - Overspending, inefficient use of funds,%;

X2 - Organizations with a high level of experience in project portfolio management,%;

X3 - Organizations with continuous training of staff on tools and methods of project management,%;

X4 - Organizations with career opportunities in the field of project or program management,%;

X5 - Organizations where the development of technical skills is a priority,%;

X6 - Organizations where the development of leadership skills is a priority,%;

X7 - Organizations where the development of business skills is a priority,%;

X8 - Organizations where the development of digital skills is a priority,%;

X9 - Organizations where the development of customer orientation skills is a priority,%.

Summary data for correlation-regression analysis of the influence of factor values on the effectiveness of projects are given in Table 2.

Table 2 Summary data for correlation and regression analysis of the impact of the level of project management implementation on project effectiveness*

Region	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Global	0,69	0,11	0,51	0,61	0,47	0,68	0,65	0,58	0,50	0,59
Africa	0,72	0,08	0,54	0,64	0,40	0,78	0,70	0,61	0,56	0,67
Asia	0,69	0,10	0,56	0,60	0,43	0,62	0,59	0,57	0,49	0,62
Australia	0,67	0,13	0,36	0,48	0,31	0,57	0,56	0,52	0,40	0,57
Brazil	0,65	0,13	0,45	0,53	0,36	0,70	0,60	0,64	0,41	0,43
Canada	0,70	0,12	0,47	0,56	0,48	0,69	0,68	0,58	0,47	0,58
China	0,69	0,10	0,77	0,76	0,69	0,73	0,70	0,66	0,56	0,76
Europe	0,68	0,13	0,46	0,63	0,43	0,69	0,62	0,56	0,48	0,52
India	0,72	0,09	0,65	0,67	0,62	0,75	0,70	0,70	0,69	0,70
Latin America	0,64	0,13	0,47	0,47	0,38	0,66	0,68	0,58	0,51	0,44
Middle East	0,71	0,08	0,50	0,61	0,42	0,74	0,65	0,61	0,52	0,56
North America	0,70	0,12	0,44	0,56	0,45	0,66	0,64	0,54	0,47	0,58
United Kingdom	0,67	0,13	0,44	0,66	0,66	0,41	0,65	0,56	0,48	0,59

* **Source**: generated by the author according to PMI (2020)

Because of the correlation-regression analysis, an economic-mathematical model was built, which has the following form:

$$Y = 0,77 - 0,83\ X_1 - 0,28\ X_2 - 0,004\ X_3 + 0,22\ X_4 + 0,26\ X_5 - 0,21\ X_6 - 0,13\ X_7 + 0,54\ X_8 + 0,16\ X_9$$

This equation shows that the most practical of the nine factors selected is an inefficient use of funds, organizations

with a high level of experience in project portfolio management, organizations with priority in technical skills, and career opportunities. While the statistically significant factor behind t-statistics is the loss rate factor, the share of organizations with a high level of experience in project portfolio management, the share of organizations where the development of technical skills and the development of customer focus skills are a priority. The quality of the model is quite high R-square - 0.95, normalized R-square - 0.83.

After excluding insignificant factors (X_3, X_4, X_6, X_7, X_8) the regression equation took the form:

$Y = 0{,}63 – 0{,}55\ X_1 – 0{,}17\ X_2 + 0{,}10\ X_3 + 0{,}25\ X_4$

X_1 – Level of losses,%

X_2 – Organizations with a high level of experience in project portfolio management,%;

X_3 – Organizations where the development of technical skills is a priority,%.

X_4 – Organizations where the development of customer orientation skills is a priority,%.

In the process of identifying correlation-regression relationships between project performance and factor values, in addition to building an economic-mathematical model, the coefficient of multiple regression, coefficient of determination, standard error, Student's t-test were calculated, which is graphically presented in Table 3.

Table 3 Indicators of regression statistics *

Regression statistics	
Multiple regression coefficient R	0,925851
Coefficient of determination R-square	0,8572
Normalized coefficient of determination R-square	0,785801
Standard error	0,011397

* **Source:** author's calculations

Given the high values of the coefficients of multiple regression and determination, this dependence is quite natural. The indicator of variance, the significance of F, and the indicator of F-statistics indicate a sufficient level of reliability of the evaluation results.

Based on the analysis, the most practically significant factors influencing the effectiveness of project implementation are technical skills and focus on meeting consumer needs. Based on the rapid industrialization and digitalization of developed countries, it is obvious that the technical skills of project managers and managers are the main direction of improving activities in this area. Besides, it is determined that there is a problem of irrational use of funds allocated for project financing, so it is obvious they need to optimize processes in project management to minimize losses through the introduction of LEAN technologies and process automation through the AIGLE approaches.

Having adopted the principles of the LEAN concept, we have formulated the main types of losses in project management, which include:

= Overproduction;

= Simultaneous implementation of several sectoral projects awaiting practical implementation;

= Too long duration of certain processes and operations, overspending of material and human resources;

= High financial costs for project implementation and irrationality of their distribution;

- Long waiting time due to bureaucratic procedures, as well as due to changes in project stages and authorization of document processing;
- Inaccuracy and duration of information processing due to lack of necessary skills of employees in the field of information technology;
- Accumulation of unfinished projects due to lack of material conditions and financial resources for their further implementation;
- Unnecessary operations in the project, i.e. projects go through unnecessary stages due to insufficient qualifications of employees, breaks for training, and advanced training.

According to the LEAN manufacturing philosophy, there are seven traditional types of losses or ways to add value that are common to manufacturing systems. These include overproduction, transportation, relocation, waiting, stockpiling, and over processing, production shortages of products or parts. Existing LEAN tools and techniques are often used to minimize losses, but a more promising area of application is their combination with advanced Industry 4.0 technologies, which can also be used to eliminate losses in advanced production systems. The loss minimization matrix through the joint implementation of LEAN-technology and Industry 4.0 technologies, which these technologies help to reduce, is shown in Table 4.

Table 4 Loss minimization matrix due to joint implementation of LEAN-technology and Industry 4.0 technologies

Tools/techniques	Wastes						
	Transportation	Motion	Waiting	Inventory	Unnecessary Processing	Overproduction	Defectives
LEAN-technology							
Cellular Manufacturing	×	×	×	×		×	
Setup Reduction			×	×	×	×	×
Quality Control				×			×
Total Productive Maintenance, TPM			×				×
Production Smoothing			×	×			
Kanban			×	×		×	
Work in Process (WIP) Reduction				×		×	
Supplier Development			×	×		×	×
Jidoka		×		×			×
Computer Integrated Manufacturing (CIM)		×	×		×		×
INDUSTRY 4.0							
Additive Manufacturing (3-D Printing)			×	×	×	×	×
Augmented Reality	×	×					×
Simulation & Virtualization	×		×		×		×
Adaptive Robotics	×	×	×		×		×
Internet of Things (IoT)			×	×		×	×
Data Analytics	×		×	×		×	×
Cloud Computing		×	×		×		

*Source: formed by the author on the basis VDI 2870 [32]

The mechanism of implementation of LEAN-technologies and Industry 4.0 technologies to ensure the goals of lean production is presented in Fig. 6. The figure groups most of the methods of LEAN-technologies, which are described in VDI 2870 (2013). As mentioned earlier, it is important that these methods can be supported by Industry 4.0 technologies, but require a high level of staff technological skills. Besides, the developed mechanism assumes that visualization and communication technologies support LEFN methods - "physical level" technologies and act as a link between their combination with the "digital data level".

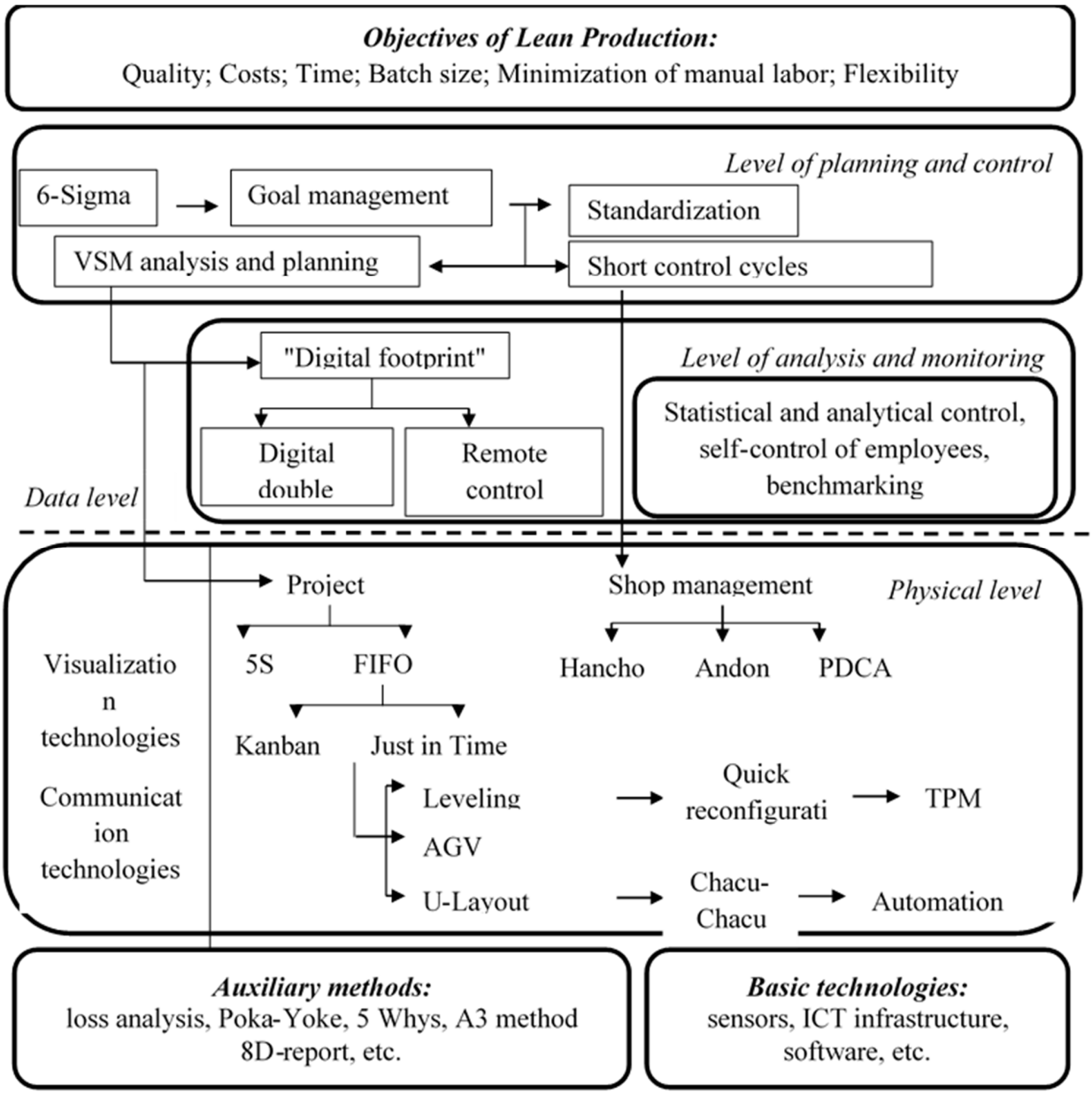

Fig.6 The mechanism for implementing LEAN-technologies and Industry 4.0 technologies to ensure the goals of lean production*
* **Source**: formed by the author based on VDI, (2014) [33]]

5. Disscussion

Analytical review of project management implementation indicators has demonstrated several important trends in project management in the world. The most common trends in project management development at the global level are an investment in technology (53%), certification of specialists (51%), development of a culture of organizational change (53%), attracting foreign investment from sponsors (61%) and project management priority as a core value (69%). Besides, 8 out of 10 project managers believe that project portfolio management is becoming a critical factor in influencing business success. (Axelos, 2019 [34])

The most successful areas of application of project management, whose projects meet the goals and expectations of organizations, include energy, finance, IT, and telecommunications. The inefficiency of project implementation directly depends on the efficient use of

resources, especially financial. Globally, companies are losing $ 114 million for every $ 1 billion spent on projects and programs due to low project efficiency. Compared to the global average, Australia, Brazil, Canada, Europe, Latin America, North America, and the United Kingdom use the least efficiently. It is inefficient to spend from 123 to 133 million dollars for every billion spent. These data are closely correlated with project performance indicators. After all, organizations that use proven project management practices spend 28 times less money than their colleagues who do not have a well-established practice and culture of project management (Wellingtone, 2019 [35]).

Based on the analysis of the impact of the level of project management on the effectiveness of projects, an economic-mathematical model is built, which demonstrates a fairly high coefficient of multiple regression R = 0.92, which indicates a very close relationship between performance and factor values. The most significant factor influencing the effectiveness of projects is the indicator of technical skills of employees, an increase of 1% leads to a significant increase in project effectiveness by 10%. The level of financial losses harms the effectiveness of projects, which is natural, but unlikely due to the level of p-value equal to 0.1. Regarding the value of the coefficient of determination R^2, the obtained correlation-regression model $R^2 = 0.78$, the dependence of increasing the effectiveness of projects by 78% is due to selected factor values, the remaining 22% are due to other factors affecting the effectiveness of projects but not included in the regression model. The results of the regression analysis confirm the findings of Biedermann (2016) [36], who argues that maintenance needs to be changed to the requirements of Industry 4.0, and emphasizes the need for knowledge and data management to ensure the goals of lean production.

In the proposed mechanism for the implementation of LEAN-technologies and Industry 4.0 technologies to ensure the goals of lean production, each of the presented LEAN methods and technologies Industry 4.0 ensures the implementation of at least one of the goals of lean production. The mechanism is based on auxiliary methods of lean production (loss analysis, Poka-Yoke, 5 Whys, A3-method, 8D-report, etc.), which can be enhanced by digital technologies (Sanders et al. 2016; Prinz et al. 2018; Dombrowski & Richter, 2018; Hartmann et al., 2018; Hoellthaler et al. 2018) and basic industry technologies 4.0, such as sensors, ICT infrastructure, software, etc., which are basic for industry 4.0 technologies.

At the heart of the mechanism are four levels of governance with interrelated methods: the level of planning and control, the level of analysis and monitoring, the level of digital data, and the physical level.

Visualization and communication technologies, together with interrelated methods and technologies, transmit information through the digital data level to the planning and control level, or the project analysis and monitoring level. At the level of analysis and monitoring of the project, several methods are proposed for use, which checks the real situation and analyzes the obtained data. The proposed methods in general can be used for monitoring and data analysis as a manufacturing enterprise or shop, and at the level of project implementation.

6. Conclusion

The result of this study is a developed economic and mathematical model of the impact of the level of project management development on the effectiveness of projects at the global level. It is established that the main factors influencing the level of efficiency of project implementation are the technical skills of employees, the level of financial losses, and rational use of resources, and focus on meeting consumer needs. According to the obtained results, the possibility of joint application of LEAN-technologies and Industry 4.0 technologies to minimize losses and achieve the goals of lean production is considered.

The paper substantiates the causal links between the methods and tools of the LEAN concept and Industry 4.0. The proposed mechanism for the implementation of LEAN-technologies and Industry 4.0 technologies to ensure the goals of lean production forms the order of project implementation, starting with the 6-Sigma method. The proposed mechanism is developed based on the studied causal relationships of the proposed methods, management processes, and types of losses. Based on the study, it can be concluded that all LEAN methods collected in VDI 2870 can be used in the formation of a corporate project management system using the two concepts considered simultaneously. Besides, the developed mechanism can be adapted to different types of projects, production cycles of different technological levels, different organizational structures. In further research, it is advisable to examine the possibility of implementing these technologies by various production organizations, such as mass production and serial production.

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