Analysis of interconnections between Lean and QM standards within LCIA framework

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Abstract. The ubiquitous approaches of lean management and environmental management (lean and green management) stem from the same sentiment, their driving force is of great importance in government and Russian practice, they have different tools and a general view of waste processes. However, the final result, as a rule, meets the needs of these concepts. The article is devoted to searching and beginning to correlate these approaches and find the presence (or absence) of a direct relationship through the mechanisms of built-in indicators reflecting both connections. This indicates the identity of the approaches to total social responsibility. The authors show the possibility of forming integrated indicators that reflect the results of lower approaches at each stage of the product life cycle from its planning and production to after-sales service. The results of the study, firstly, set the vector for further development of a single integrated model that unites both governments, and secondly, using an example, they simplify the interaction of traditional line-functional managers of production enterprises and heads of environmental departments, limit barriers to mutual understanding and show the goals of unity, although excellent in terms of implementation of the approach.

1 Introduction

Modern world practice of training specialists in the field of environmental science is quite extensive and offers, along with fundamental education at the bachelor's and master's levels, also various short-term courses. Various sources indicate that in 2023 in the USA alone, more than 1,500 universities offered various environmental sciences courses [1-2].

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The leaders of education in this direction are the USA, UK, Netherlands, Switzerland, China, Singapore, Australia and Canada [3]. An interesting fact is that a number of educational institutions classify the fundamental education of bachelors of environmental science as a Bachelor of Art, while other universities classify this education as a Bachelor of Science. In the United States and Europe, environmental science degree programs are accredited by the Accreditation Board for Engineering and Technology (ABET) and the National Environmental Health, Science and Protection Accreditation Council (EHAC) [4].

In the Russian Federation, 572 higher education institutions offer 946 undergraduate programs in the field of Ecology and Environmental Protection.

An analysis of more than a hundred educational programs at the bachelor's level in environmental sciences showed that the vast majority of universities build into the curriculum courses that include the study of the ISO14000 Environmental management standard (Russian equivalent - GOST R 14000). The Federal State Educational Standard of Higher Education - Bachelor's degree in the field of study 03/05/06 "Ecology and Environmental Management" does not include mandatory requirements for professional disciplines or the content of this block of competencies. Also, the undergraduate level does not require knowledge in the field of management.

The unanimity of curriculum developers emphasizes the fundamental importance of this standard for the basic education of specialists in the field of ecology and environmental protection.

Rapidly growing requirements for Russian manufacturers in the field of product quality with simultaneous tightening of control over their impact on the environment determine the need to analyze activities not from the standpoint of the product, but from the standpoint of the process of its production. The result is a new combined approach - Life Cycle Assessment (LCA).

A Life Cycle Assessment (LCA) measures the environmental impacts of a product or service [5]. Essentially, this term includes the analysis of the process of creating a product from the extraction of raw materials, production, application, repair, maintenance, transportation of the product at all stages to disposal or waste treatment.

Muralikrishna and Manickam integrate the LCA approach into the concept of the ISO14000 standard through goal setting, description of flows within the production system in terms of its interaction with the environment, assessment of such interaction and post-facto analysis [6]. Pennington and Rydberg develop the idea of Muralikrishna and Manickam and determine how LCA can be reflected in the marketing and product strategy of a manufacturing company, as well as determine the vector of strategic planning and the framework for positioning the company in society [7]. They also introduce into scientific use the concept of LCIA (life cycle impact assessment), which more accurately reflects the idea of building a product system from the point of view of the impact of production on the environment.

On the one hand, an accurate assessment of the LCIA indicator makes it easier for environmentalists to monitor the environmental impact of an enterprise. On the other hand, such an assessment forms a clear system of indicators, analysis of the structure and values of which allows the manufacturer to concentrate on optimizing the most problematic areas.

In the traditional methodology of quality management and lean-manufacturing, losses are considered irrational, non-ergonomic and generally unnecessary actions in the process that slow down its cycle. The LCIA concept, reflected in the ISO14000 standard, sees as waste actions that unsustainably consume resources or unsustainably produce waste.

The purpose of this study is to search and attempt to correlate these approaches and prove the presence (or absence) of direct relationships. If the hypothesis is confirmed, it will be possible to conclude that different approaches with different goals are identical in the final results. This means that speeding up processes by eliminating wasteful activities

improves the interaction of production with the external environment in accordance with the understanding of LCIA and the ISO14000 standard in general.

This provision, if confirmed, simplifies the interaction between traditional line-functional managers of production enterprises and employees of environmental departments, reduces barriers to mutual understanding and shows the unity of goals, although different in terms of implementation approaches.

2 Materials and Methods

The study was conducted from 2020 to 2023 at a mechanical engineering enterprise that decided to introduce a lean-manufacturing approach into its production processes. In November 2020, the enterprise was certified according to GOST R ISO14001-2016. After certification, the enterprise introduced a system of regular internal audit of the environmental management system, but during the audits only deviations from the indicators approved by the enterprise were checked.

To correlate the approaches of the current study, indicators were identified that could characterize the change in the situation from the perspective of lean-manufacturing and the environmental management system throughout the life cycle of product creation ("values" in lean terminology). The set of indicators is shown in Table 1.

Table 1. A set of indicators for correlating changes in lean-manufacturing and environmental management systems.

LCIA stage	Lean-manufacturing approach	Environmental management approach	Indicator
1. Product planning	Reducing the number and duration of production operations	Use of energy saving technologies	Product production time (planned), days
2. Purchase of raw materials	Reduction of warehouse stocks	Reducing the volume of disposal of overpurchased raw materials, as well as those beyond their expiration dates	Volume of warehouse balances, rubles
3. Manufacturing	Reducing the production of defective products	Reducing the volume of waste disposal	Scrap volume, %
4. Control	Reducing production cycle times by reducing inspection operations	Reduction in the amount of energy consumed (reflects a reduction in the duration of the production cycle due to the reduction / elimination of waste operations	Number of employees with a "personal quality mark", people
5. Service	Reducing the number of complaints from the Customer	Reducing the number of orders from regulatory authorities	Number of deviations from planned internal audit results

Source: Compiled by the authors.

The results of the indicators were recorded during 2021-2023, however, the results of 2021 cannot be considered completely reliable due to the specifics of work during the COVID-2019 pandemic. During this year, audits were carried out remotely, and the production process itself was subject to force majeure.

3 Results

Results of Stage 1.

Product production planning has not undergone fundamental changes. As a result of changes in technology and updating of the technological park (replacing equipment with more high-performance ones), 28 operations were displaced or replaced in 2020, more than 50 operations in 2021, 94 operations in 2022 and 67 in 2023. The slowdown in 2023 is due to the cancellation of planned purchases of new equipment due to the transition to domestic production of equipment and parallel imports, which slowed the pace. It is interesting that the replacement of equipment did not have a significant impact on production time, since in 2022-2023 production volumes were significantly increased, there was a massive recruitment of personnel (+32% of personnel over 2 years) and, accordingly, a slowdown due to additional time, spent on training new staff. Since a third of the employees were in one way or another in the process of training, developing skills and improving their qualifications, this slowed down the overall pace of production and, looking ahead, increased the volume of production of defective products. However, the replacement of higher-performance equipment was able to compensate for this slowdown, demonstrating a decline in the rate of reduction in terms, but still reducing them. Thus, it can be confirmed that the Stage 1 indicator (production time (planned)) reflected both approaches and demonstrated positive changes.

Results of Stage 2.

Sharp inflationary processes and breaks in logistics connections in 2022-2023 significantly affected the volumes of purchased raw materials and, accordingly, warehouse balances. Purchasing services traditionally demonstrate a tendency to consolidate purchases during periods of rising inflation, which is what happened at the enterprise. In general, overproduction in the field of procurement has already been observed at the enterprise under study on a fairly large scale. According to the expert assessment of the enterprise management, 2.5 times more raw materials were purchased than required. The reasons for this were:

1) the dictates of monopolistic suppliers;
2) imperfection of procurement legislation;
3) lack of understanding of raw material requirements due to significant fluctuations in scrap volume.

During the observation period, the volumes of overproduction in the field of procurement increased by 24%, that is, they exceeded the traditional excesses. Accordingly, one could conclude that there is a negative trend in this area. Thus, to confirm the hypothesis regarding this indicator, the observed volume of recycling of repurchased raw materials, as well as materials beyond their expiration dates, should have increased. Indeed, an analysis of the procurement of the enterprise under study using the keywords “removal and recycling” revealed that in 2023 the number of such tenders exceeded the same values in 2021 by 1.8 times, and the total cost of services increased by 2.7 times. From this we can conclude that the hypothesis is confirmed in terms of the Stage 2 indicator.

Results of Stage 3.

As described above, 2022-2023 became a period of global recruitment (+2300 people over 2 years), which entailed a significant period of training, skills development and a slowdown in production processes. It should also be separately noted that both production workers and supervisors were hired, which led to a large number of defects produced. An important negative trend was the slow detection of defects (not at the point where the defect appeared, but at subsequent stages). However, in order to confirm the hypothesis, it is also necessary to estimate the volumes of industrial waste disposal - they should grow in accordance with the direct correlation of indicators. Indeed, as described in the results of Stage 2, recycling volumes increased both quantitatively and in monetary terms. An objective assessment is made difficult by the lack of classification of purchases in terms of the source of the recycled material: whether it was the result of a manufacturing defect or a defect identified at control sites. With some assumption, we believe that the hypothesis in this indicator was confirmed.

Results of Stage 4.

The number of control stages has not decreased; moreover, the duration of these stages has increased due to the low skills of newly hired controllers and an increase in production volumes. At the same time, if we take as a calculation indicator the ratio of the volume of products produced to the duration of control operations, then there is progress. However, in quantitative terms, nothing has changed. There was also no reduction in the amount of energy consumed. On the contrary, the enterprise switched to working in 3 shifts (until 2021, work took place in 2 shifts and not in all areas). Calculation of absolute values showed that per unit of production the volume of energy consumption increased by 17%. According to the expert assessment of enterprise managers, this is due to an increase in the number of shift changes and interoperational intervals, however, according to production operators, batch volumes have also increased, which always increases the volume of energy consumed per unit of production. This is due to the lot's shelf life. Also, the reason for the excessive consumption of electricity is the large-scale repair work carried out at the enterprise during this period. The indicator of growth in the number of employees with a personal quality mark also has a negative trend (decrease in the number of such employees), which is typical for a period of growth in the total number of personnel and temporary staff turnover. With some assumption, we believe that the hypothesis in this indicator was confirmed.

Results of Stage 5.

Complaints from the Customer in general are not a typical practice for this enterprise, since a representative of the Customer is present at the enterprise during the production process. Thus, product acceptance occurs in stages during production, which ensures 100% acceptance of finished products that have successfully passed testing. In 2021, the enterprise underwent a scheduled inspection by Rospotrebnadzor, but no open information was found on the availability and number of regulations. A positive opinion is formed due to the absence of entries in the register about revoked licenses or refusals to issue sanitary and epidemiological certificates. Regarding the number of deviations from the planned internal audit results, in 2022 the enterprise identified 35 deviations, of which 25 were minor. Compared to 2021, the total number of deviations has increased (from 33 to 35). Deviations identified during inspections are mainly related to violations or incomplete compliance by staff with requirements, which, again, is associated with large-scale recruitment of new personnel. Regarding the indicator of this stage, the hypothesis was not confirmed.

As a result of the analysis, the authors concluded that the selected indicator was incorrect. It is likely that the results of external audits should be assessed.

4 Discussion

The study showed that, in general, both approaches are aimed at reducing operations, actions, processes, called "losses" in terms of these approaches, but they use not just different tools for this, but different angles of view on the same problem. An important prerequisite is the initial driving force: in European countries it is most often the tightening of environmental legislation, in Russia the initial need to increase productivity was caused by the desire to increase production margins, and now the main reason is a real shortage of personnel. The shortage of personnel forces us to look for ways to increase production with small forces. However, what really matters is the final result, since, regardless of the motivation, the desire of both approaches is aimed at identical goals.

Foreign studies have repeatedly pointed out the existence of relationships between lean and green management. Hallam has conducted a good literature review of publications on this topic [8], most of which indicate that the approaches are not mutually exclusive [9–11]. His attempt to integrate both approaches is noteworthy (Fig.1).

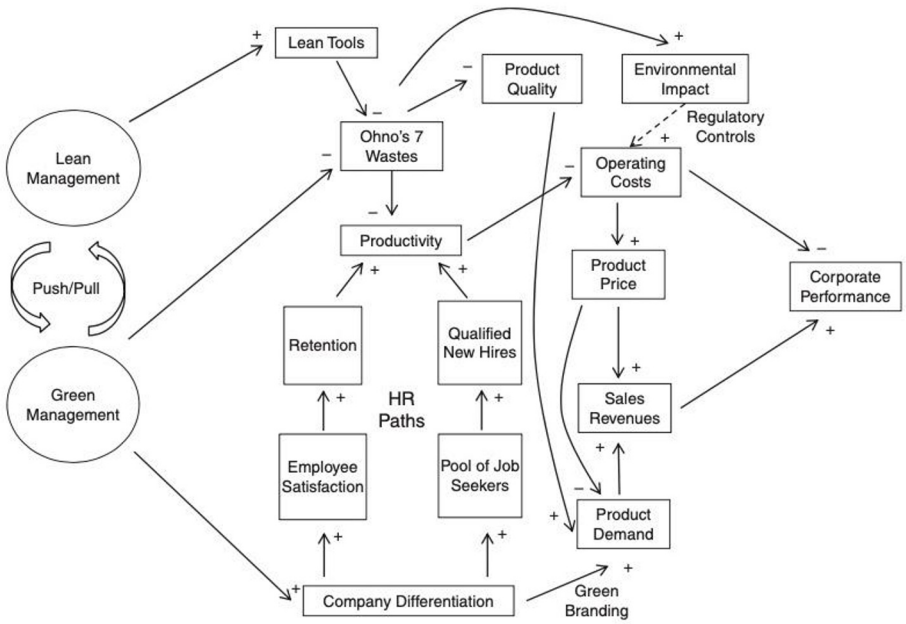

Fig.1. Management model integrating Lean and Green with firm performance.
Source: Hallam [8]

However, most often the connection between the approaches is proven by the fact that as a result of the implementation of lean production, the goals of environmental management are simultaneously achieved, that is, as if lean production is primary in this understanding. To date, no serious integrated models have been developed, just as the ISO14000 and ISO9000 standards have not been combined. The need to develop some kind of integrated approach is clearly ripe, but this approach requires, first of all, goal setting.

And, as mentioned above, different initial driving forces determine different goals, and the same result is viewed from different perspectives. Thus, the question remains debatable as to whether this is acceptable, whether enterprises accept parallel approaches with their own individual tools, or whether the development of new tools is necessary.

The current study has only scratched the surface of the possibilities for developing indicators that incorporate both approaches. The authors show that such indicators can be formed along the entire life cycle of a product from its design to its after-sales service. At the same time, the number of indicators is clearly insufficient, but clearly demonstrates this possibility. Similar more in-depth studies at each stage of the life cycle with the resulting formation of a balanced system of indicators seem promising.

5 Conclusion

The study showed a direct relationship between the approaches of Lean manufacturing and Environmental Management within the framework of the LCIA concept. Despite significant differences in initial goals and different tools, the final result reflects the needs of both approaches. The authors showed the possibility of forming integrated indicators that reflect the results of both approaches at each stage of the product life cycle from its planning and production to after-sales service. The results of the study, firstly, set the vector for further development of a full-fledged integrated model that combines both approaches, and secondly, in practice it simplifies the interaction of traditional line-functional managers of production enterprises and employees of environmental departments, reduces barriers to mutual understanding and shows the unity of goals, although excellent in terms of implementation approaches.

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