The concept of implementing lean manufacturing technologies in transportation enterprises

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Abstract. The article explores the techniques and tools of lean manufacturing, and formulates the concept of implementing lean approaches in transportation enterprises. Lean manufacturing technologies are necessary for the transportation industry, and their application is already in progress in many companies with varying speed and effectiveness. To achieve this, firstly, existing practices in implementing lean manufacturing technologies in transportation enterprises are analysed, secondly, the organisation of flow of individual transportation and logistics operations is identified as the fundamental basis for a lean transformation, and thirdly, a possible approach to revising the overall organisation of transportation enterprises is proposed to realise a continuous flow through the transition to network-centric logistics. The scientific novelty of the study is that it presents and analyses the problem of contrasting partial and systematic implementation of one of the most promising management methodologies, and identifies a direction for formulating specific recommendations for transportation enterprises. The main idea of the concept is that transportation enterprises are encouraged to focus on the flow of information rather than material.

1 Introduction

Lean manufacturing is triumphantly advancing in all areas of management, from the public sector to personal efficiency. While 20 years ago it was possible to say that the lean approach might be effective in some management areas but not in others, today it is more or less universally acknowledged that lean transformation is inevitable for all areas of management, and those who cannot learn to think in this paradigm and use lean manufacturing technologies will be left behind. The question of lean transformation has long moved from the realm of "if" to the realm of "how".

This difficulty is related to another contradiction that transport enterprises face, which is that the effectiveness of implementing the concept of lean manufacturing is significantly dependent on how far the serviced industry has progressed in lean transformation. The

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transportation enterprise is interested in reducing unnecessary movements and other losses, and the lean manufacturing methodology teaches that, among other things, it is necessary to minimize the size of the processed batches and eliminate queues to achieve this. However, due to the secondary role of the transportation enterprise in the serviced industry, such batch reduction is only possible if it had previously set the batch sizes and formed the queues for delivering goods. Transportation enterprises have to exist within the framework of the infrastructure that was created to process a certain size of batches, serving enterprises that were also adapted to these batches. They usually have no ability to influence the organization and traditions of the serviced industry or change the sizes and frequency of ordered batches. As a result, after reaching the level of working with the batches of goods that come from customers, the transportation enterprise has no possibility to further balance the flow, reduce batches, and eliminate queues.

There are quite a few enterprises that either originally worked with a minimum batch size dictated by the market or have already reached this level within the implementation of lean manufacturing technologies. This is almost all B2B services in passenger transportation. If small groups are sometimes combined into one bus in the tourism industry, then it is almost impossible to imagine this in the corporate service industry. In freight transportation, the sizes of batches are dictated by freight receivers, leaving the possibility for order consolidation only for companies that serve the "last mile" for small receivers, where a rapid reduction in batch sizes can be observed across the industry.

A number of works and publications devoted to the "problems of implementing lean manufacturing" actually consider not problems but obstacles, i.e., quite surmountable circumstances that hinder the implementation and broad use of lean manufacturing tools. For example, they identify a shortage of time and resources, the lack of a development program, the reluctance of workers to use new technologies, the cost of implementing these technologies, the type of management thinking, and the misunderstanding of lean manufacturing concepts [1,2,3,6,7,8]. The common feature of all these obstacles is that their solution can be trivially reduced to an increase in the budget or implementation term, and as we know, any problem that can be solved with money is not a problem but an expense. Moreover, some obstacles, such as "costliness," are actually less characteristic for lean manufacturing than for other management methodologies. Conversely, the implementation of lean manufacturing technologies is associated with a sharp reduction in costs since the frugality philosophy is installed not on computers or regulations but in the heads of business process participants. Thus, in a systematic review of literature on the implementation of lean manufacturing published in February 2023, Dr. Sina Moradi concludes that it is people, not circumstances, technologies, or resources, that are the root cause of all obstacles, opportunities, and consequences of implementing lean manufacturing technologies [15]. Multiple productivity increase at zero cost in the first few weeks after implementing lean manufacturing is not something unrealistic for the production industry. Some difficulties in applying lean manufacturing are specific to a particular area of transportation services.

2 Materials and methods

If we take a look at lean production as a set of tools to be learned and implemented where appropriate, with minimal adaptation, the standard list of lean production technologies includes TPM (total productive maintenance), visual management, standard procedures, just-in-time, mapping, built-in quality, 5S organization, kaizen, and kanban. Managers naturally turn to the methods that can be classified as “low-hanging fruits” to achieve maximum short-term benefits before moving on to a more profound review of management practices in the organization. Unfortunately, this leads to the company becoming slightly

more efficient in its specific aspects, without achieving significant success in a strategic plan, and the lean production methodology is rejected as inefficient. To fully benefit from lean production, a complete shift of the transportation company to lean rails is required, which requires a revision of work and management organization. Unfortunately, implementing individual elements of lean production on a point-by-point or local basis can move the enterprise in the opposite direction from lean.

In several studies on adapting the concept of lean production to the transportation industry, authors typically either examine the lean transformation of large-scale business processes, of which transportation is just one link, or study transportation enterprises that tend to aim for parallel processing of goods through batch size optimization [9-11], among others.

The methodology itself provides a clear answer to the question of how to expand the lean production approach to various areas of activity, by embodying for them the key idea of the flow method. In the chapter "Organizing the flow" of their fundamental work "Lean Thinking: Banish Waste and Create Wealth in Your Corporation" [17], James Womack and Daniel Jones use the following formulation: "We assert that the principles of flow apply to any activity" [17].

The universality of this principle is also emphasized in other lean production guides. The application of kanban labeling, optimization of the operator's workspace, visual cue systems, the Poka-Yoke principle, and other purely production methodologies, all require a certain value-creating node to optimize, and the business processes and characteristics of the relevant nodes are unique to each business. For any organization, regardless of specific business processes, the approach to what activity is considered efficient (that which creates value flow) and what is surplus, can be conceptually revised, and how to find and get rid of excesses to achieve a single-piece flow organization. "It is most appropriate to teach the philosophy of lean production through the example of commodity production (where it first originated). Once managers learn to see the flow, they can apply the universal principles of lean production to any activity. The focus should be on managing the flow of value creation for a particular product or service, eliminating organizational barriers, creating a lean enterprise, putting the "right" equipment in the necessary sequence, implementing lean production methods and ensuring continuous flow" [17].

The developers of the lean production methodology, namely Womack, played a crucial role in the discovery and popularization of the term Lean Manufacturing in the Western world, so he can be considered as a full-fledged developer of this methodology, just like Taiichi Ohno [16]. The cornerstone on which the success of the lean production ideology is based is the creation of flow.

Hence, the main problems that managers face when implementing lean transformation in transportation companies arise. Is it possible to compete in the modern transportation market by focusing exclusively on delivering small batches of goods, for which continuous flow can be achieved? For passenger transportation in the B2C sector, a shift from batches and queues to continuous passenger flow may be economically justified. But if a customer needs to transport a container from point A to point B, dividing it into a stream of individual packages is absurd. Of course, one could argue that delivering goods from the container one by one can provide greater value to the customer, since they won't need to store the goods. However, this change does not improve the efficiency of the transportation company but rather requires a revision of the chain for which the transportation company is a link. Moreover, in passenger transportation, reducing the batch size is possible only in certain cases, such as reducing the capacity of a train, which is unlikely to be economically feasible.

The quote from Womack sets a certain framework that does not immediately reveal the potential for applying the fundamental idea of lean production to move away from batches

and queues in favor of a continuous flow of individual items in an industry where batch shipments are part of the problem. Specifically, Womack suggests focusing on the flow of those goods and services that the enterprise directly provides to the customer. It is proposed to move to a meta-level and try to apply lean production technologies to how the enterprise serves not material but information flows within itself. The idea is that if changes in the nature of orders and batch sizes in the served industry are beyond the scope of the transportation company's influence, then it can reform the information flows and its own structure without restrictions. As N. Davydova formulated it: "... the main regularity of lean transformations is to start all changes from oneself. Everything external is a reflection of the internal state" [4].

To have the opportunity to review the potential scope of implementing the lean production concept in the transportation industry and discuss a full-scale lean transformation, it is crucial to go beyond the framework set by Womack and Jones. If we consider the size of batches shipped to customers as the main limiting factor, the manufacturer and carrier are in fundamentally different conditions. The manufacturer will immediately receive feedback on changing their policy: just allowing customers to order smaller batches for the same price will cause all your clients to instantly restructure, reducing the average order size. A transportation company may be willing to transport even one bucket of sand at a time, but they will still be ordered to transport one hundred tons because the contract between the quarry and the glass factory will not be revised due to the emergence of additional logistics possibilities for small batches. Lean production technology specialists may argue that it is simply necessary to show the sand quarry and the glass factory all the benefits of transitioning to small batches, but unfortunately, initiating a lean transformation in a company that serves a transportation company is practically impossible in real life.

Instead of struggling to balance the flow of goods delivered within orders, that is, transforming the material flow, it is possible to focus on the information flow within the transportation company. Balancing the information flow fully corresponds to the principles of lean production, only the point of application changes. If this can be done, then an increase in the overall efficiency of the enterprise can be observed while fully maintaining external characteristics. The enterprise will still transport passengers in whole carriages and goods in whole containers, but it will do so more reliably, with better quality, cheaper, and faster. And, most importantly, the information flows cover the enterprise and shape its work at all levels, dominating in terms of required resources and value for the overall efficiency of the enterprise.

For the material flow, the directions for optimization are visible, for example, overproduction, which results in empty spaces in transportation, which are transported without loading, that is, without creating value. To find such points of loss due to unevenness in the information flow, it is necessary to model various extreme cases. What if the batch processing quantum cannot be reduced, and it is huge? That is, a hypothetical transportation company processes exactly one delivery, which is fantastically large or complex, throughout its entire existence. Such a company, for example, can be considered a space mission to deliver astronauts to Mars because such events are carried out within the framework of a project approach and, therefore, by definition of project management, are micro-enterprises that are created "for the occasion". In such a transport project-enterprise, the information flow will obviously be extremely non-uniform since at the beginning of the project, there is intensive work on planning, testing, and calculations, and at the end, the information exchange is reduced to a minimum since the cargo is already in transit and hardly anything can be influenced. And in this extreme case, the connection between the unevenness of the information flow and all the losses and risks typical of project management is absolutely obvious. How can we balance such a flow to achieve greater

manageability and all the benefits of lean production if it is impossible to deliver the cargo in several stages by definition? The only possible option is to move some of the calculations to the end of the project. That is, instead of planning for the flight from launch to landing on the red planet and then launching the spacecraft and praying that everything goes according to plan, it is necessary to provide astronauts with the opportunity to independently perform calculations and control the spacecraft on approach. And the modern space industry is already moving in this direction, achieving maximum flexibility throughout the mission.

To visually trace the information flow, a case can be considered where the delivery itself makes up an extremely small part of the transportation company's service costs. This could be, for example, the delivery of electronic goods over the network. An online cinema cannot be considered an extreme case of a transportation company, but its CDN network that services it can be seen in this regard. Without going into technical details, it should be noted that the largest global CDN providers (such as Akamai, AWS CloudFront CDN, Edgio, Cloudflare CDN, Google Cloud CDN) operate in a blackbox mode, where traffic and computational power balancing within the network occurs automatically and is not tariffed, and the client only pays for the upload/download of information to the network from external sources. In other words, instead of negotiating with the client the parameters of a dedicated server, as traffic exchange market participants did at the stage of its formation, providers are mass transitioning to completely eliminate interaction between the client and the "center" and any pre-agreements and constraints, allowing servers in their own network to independently decide how to satisfy each individual client request. The interaction between servers based on well-thought-out algorithms allows for simultaneously increasing the flexibility and transparency of the system. If a client that rents a server and a dedicated channel to it changes the nature of consumption, for example, due to the expansion of the broadcasting network, a data center (that is, a provider that operates according to the outdated scheme of providing capacity by renting equipment) can react only when the client faces a shortage of resources or when analytical software detects potential problems and reports them to the system administrator. And, if the same situation occurs with a user of a modern CDN provider, the network will instantly adapt, while there will be no loss in the work of administrators and re-negotiation of the contract with the client.

Network centricity implies that system elements act independently, obtaining necessary information from the common network, so this definition more accurately characterizes the approach under consideration than just "network logistics"

In addition to standard administrative work, marketing, human resources management, and infrastructure management in the transportation industry, there is a constant stream of various logistical tasks. While logistical tasks arise in other fields of activity, they are always new for a transportation company and are essential for its success. By logistical tasks, we mean exclusively practical tasks related to organizing logistics for a particular delivery, i.e., optimization of transportation, storage, and support of a known cargo between known points. Logistics tasks are usually combined and processed in batches for volume savings. The solution to these tasks often focuses unnecessarily on the logistics center of the transportation company, and the implementation of deferred or phased logistics construction for individual delivery is practically non-existent. «The task of introducing lean production in convoys is to improve the quality of passenger service, reduce costs and bring enterprises to profit. In turn, this will reduce budget costs for transport enterprises. Now it is already possible to consolidate the accumulated experience and gradually begin to replicate all decisions» [20].

The scientific hypothesis is that there is a universal approach to implementing lean transformation in a transportation company, and it involves organizing a continuous flow of information through a transition to network-centric logistics.

3 Results

According to the developed concept for implementing lean production technologies in a transportation company, the focus should not be on the flow of goods but on the flow of logistical tasks. To implement this approach, there is no need to consider the logistics core of the transportation company as an independent contractor organization, where a comprehensive introduction of lean production methodologies is possible. Rejection of old management schemes, while the area of influence of such an internal contractor is sufficient to take a mandatory step of "looking around." Next, the adaptation of the enterprise will be required so that it can receive all the advantages of a uniform predictable flow of the provided solutions. Such an approach would not be a comprehensive implementation method since only one element of the system would undergo lean transformation, and the subject of this research is the search for a method for the systematic and comprehensive implementation of lean production tools in the enterprise.

Instead of decomposing the enterprise itself and isolating its individual divisions, it is proposed to switch to a functionally-oriented approach and focus on aligning individual flows passing through the entire enterprise. The simplified model of transportation company's operation is presented in Figure 1.

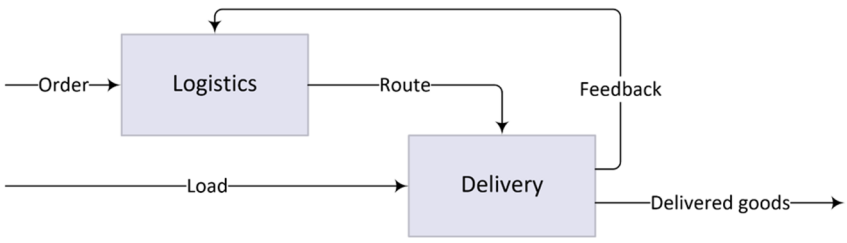

Fig. 1. Transportation company's operation model.

The model has two flows: material and information. The classical approach to implementing lean manufacturing technologies focuses on the material flow. And if you manufacture cars and switch from a conveyor designed for large batches to custom car assembly, this is the most natural approach. As the level drops (i.e. batches decrease) in the material flow, a chasm of all kinds of pitfalls opens up, making enterprise improvement a routine process. The flows themselves are independent, and if a company begins to ship one car at a time, this does not prevent them from orienting themselves towards large orders and serious customers. The customer in this situation is under pressure when his consumers buy in small batches, and his supplier (after lean transformation) works with small batches and he too begins to reduce the processing batches. This leads to a reduction in the level in other flows, as orders now come more frequently and in small batches.

For transportation companies, it is suggested to focus not on the material flow, but on the information flow. The potential difficulties in implementing lean manufacturing technologies are clearly visible in the presented scheme. Savings on scale due to parallel delivery, when goods from different suppliers are accumulated for simultaneous processing, is small, and managers easily sacrifice it in favor of greater transparency and reliability of

the process by switching to a flow of individual deliveries. The term "optimization of transportation company's operation" is practically equivalent in the respective management environment to the term "optimization of logistics operation," and companies compete in indicators such as "vehicle fleet utilization," "average cost per tonne-kilometer," and even "number of serviced drivers per one logistics manager." Full transition to processing shipments "one at a time" within the framework of implementing the lean manufacturing methodology is not considered by such companies. In other words, the transportation industry has stopped at the "parallel solution to the logistics task" among the options presented in Figure 2.

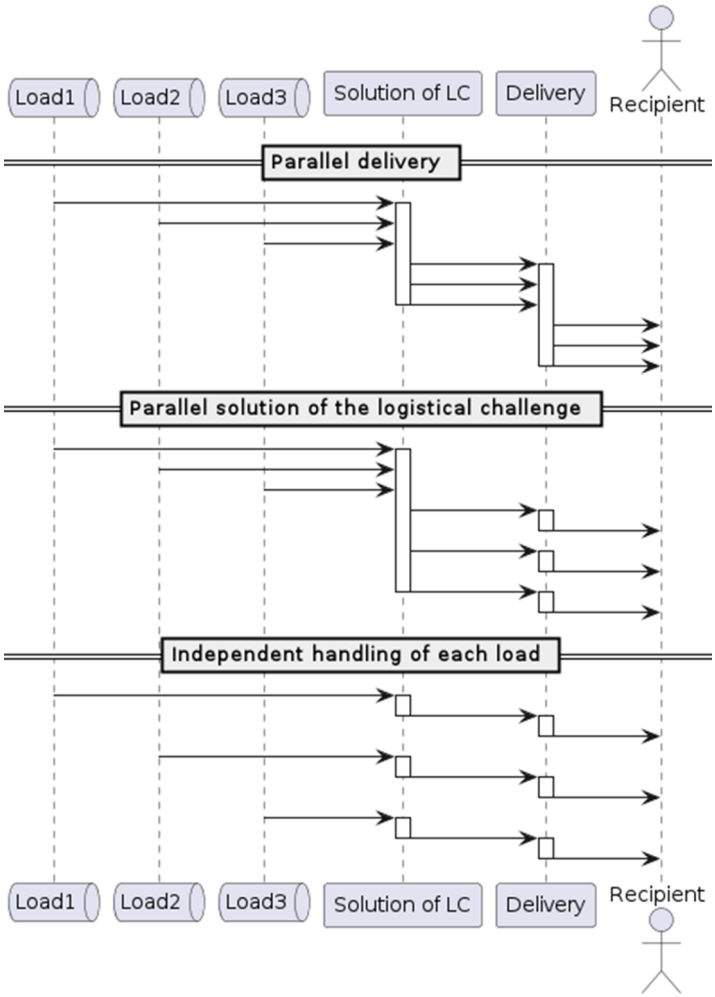

Fig. 2. Freight delivery options.

The freight delivery option considered by the transportation company becomes surprisingly similar to the cases that are discussed in business literature on lean manufacturing, 6-sigma methodology, theory of constraints, and other modern management methodologies. It is the same model where initially the factory operates, conditionally, on steam power and all workstations are connected to a single shaft that rotates the steam engine, and then electric motors appear, and the factory management in the familiar

paradigm first replaces the steam engine with a giant electric motor that still rotates the common shaft. A change in perspective is needed to take advantage of all the benefits of electrification and think to put a compact electric motor on each workstation. As long as the management of the transportation company focuses on ways to develop and improve its logistics center, the transition to the flow of individual orders and the accompanying fundamental leap in the economic efficiency of the enterprise is impossible.

If we follow the analogy with classical production, then in the framework of transition to lean manufacturing, the strategic direction of development for the transportation industry as a whole and individual enterprises today should be a retreat from the concept of the logistics center as a given. Instead, logistics should be handled by the direct executor, so that each participant in the delivery process becomes their own logistics manager, with the ability to be responsible only for their own delivery segment.

It is more difficult for transportation companies that deal with mixed cargo transportation to abandon logistics centers where it is necessary to first pick up an impressive batch of goods by trucks, then load them into wagons and deliver them by rail to the port for further water transportation. But even here, a sequential dismantling of the centralized system is possible, which will allow for a transition to a network-centric logistics approach and a flow of individual deliveries. Instead of accumulating orders and then distributing them among delivery links, overloading them based on cost per tonne-kilometer, orders can be immediately transformed into requirements such as "this cargo must be at a certain place at a certain time," and then allow drivers, train owners, warehouses, and other participants in the logistics chain to "pull" the cargo from each other directly.

To make the participant network of such a system work consistently, the concept of "takt" is used in lean production. Takt is chosen so that participants do not have to wait for each other, synchronizing the start and finish times of processing not with each other, but with the overall rhythm. It is unlikely that the same precisely timed and rhythmic work can be achieved for a complex logistics chain as for a lean conveyor, but this is another goal that, if approached, will allow for the most efficient use of network-centricity in a system.

In the presented study, it is important to outline the ultimate goal and direction of the lean transformation, which is to minimize the involvement of the logistics center in the order reception and transfer stage and to maximize the independence and responsibility of the actual performers. Ultimately, the transportation company should strive to operate in the spirit of "quantum management," as presented by Dana Zohar [18], where each participant represents a micro-enterprise that operates in its own interest within the overall flow of orders and interacts with other delivery process participants on equal terms. A network-centric reorganization will be a true lean transformation for such a transportation company.

Let's consider a typical example of delivering products to nearby stores. As part of the lean transformation, the size of the transportation naturally decreases while the frequency of delivery increases. Such cases are detailed in a number of publications [13, 17]. But this case is also interesting from the perspective of the hypothesis presented regarding the alignment of the information flow, where abandoning parallel logistics tasks seems unproductive. If 10 stores need to replenish their supplies and only 5 replenishments fit in one truck, it is logical to distribute the necessary supply between two trucks and choose the loading order to minimize the total mileage and delivery time. All logistics tasks are solved at the stage of distributing goods among the trucks; it is not possible to postpone any decisions to a later time. In this case, the information flow can be aligned by delegating some of the flow processing to the direct supplier. In the classic work scheme, the truck driver performs mechanical work, strictly following instructions. After the lean transformation, the driver must become an active participant in the business process. It is the truck crew that should receive feedback from the store, transform it, and convey it up

the chain. Not the logistics center but the crew should have direct access to information about how the warehouse stock relates to store requirements, and then the crew can independently decide to make an additional load from another company warehouse, organize a two-stage delivery to a store with insufficient capacity, and so on. And when one of the stores does not receive the ordered goods or receives something different than what was ordered, the driver will not shrug and say that the logistics people messed up, but will be involved and interested in finding and eliminating the source of the error on the spot.

The last example involves freight train transportation. It would seem that savings on the abolition of the logistics center here would be illusory, and achieving a network-centric logistics organization is unlikely. But if the same logic used for truck delivery is applied to rail transportation, an interesting perspective is revealed. Instead of a single center, in a network-centric system of rail transport operations, individual locomotives or trains can function. Building a network that maximizes the efficiency of the trains, which can gather their own carriages while following a set of understandable rules, is an extremely interesting task but it is uncertain if it can be resolved under the centralized management of the railway infrastructure. However, if each train is an independent unit with a known carrying capacity, the number of carriages and timetable, then a centralized system can take decisions on launching routes and their coordination, including uninterrupted crossing of trains on single-track lines (a task that is unlikely to be realized in the near future through purely network interaction between trains [5]). Trains could interact directly with customers through the network, using blockchain-based registries, order retrieval, and an automated system to incentivize handling complex orders. This approach somewhat deviates from the stated goal in the article of finding a way to comprehensive lean transformation since much of the work remains tied to a central location. However, railway transportation is an industry, not an isolated enterprise. An enterprise (or a unit) that works according to the principle described (every train, as far as possible, independently manages logistics while interacting with customers through the network) would have to abandon forming cargo sets "on occasion" and switch to "freight express" trains that run on a schedule. Then, interaction with the "center" would be minimized, and work within the route could be built as lean as possible, both in technical execution (as such a train would require significant improvement of loading and unloading procedures since it has a constant composition and cannot simply detach carriages at intermediate stations) and in interaction with customers. Now, the customer is not obliged to plan, coordinate and send batches in advance when they know that they can "lay" their cargo in the required volume on the day of the order as needed. Scientists have discussed similar servicing technologies [2], and they were implemented in the 1930s to 1950s. However, at that time, the initiative did not receive development due to the lack of appropriate information technology infrastructure. In 2016, the "Freight Express" technology was launched by JSC Russian Railways [19], which precisely implements the continuous movement of a train of known length and weight along a specified route, and could be a basis for the implementation of network-centric logistics.

4 Conclusions

The paper proposes a concept of implementing lean production technologies that allows us to talk not about local improvements through developed methodologies, but about comprehensive lean transformation for a complex industry such as transportation. The main problem faced by transportation companies during a lean transformation is highlighted, namely the impossibility of transitioning to a uniform flow due to the unevenness of orders from serviced companies, which operate in the paradigm of batches and queues [21]. A hypothesis is put forward according to which an alternative application point for starting a

comprehensive lean transformation in a transportation company could be not the material flow, as for production or trading enterprises, but the information flow.

The presented research has shown, using several types of transport companies as examples, that lean transformation is ideologically linked to another popular trend in modern management - the transition towards a network organization. In particular, the transition to a network-centric logistics is both the implementation of a uniform flow of individual logistics solutions (the foundation of lean production) and the shift towards a horizontal organization (a direction of quantum management).

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