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IJIEMR Transactions, online available on 21th Dec 2024. Link

https://ijiemr.org/downloads.php?vol=Volume-13&issue= Issue12

DOI:10.48047/IJIEMR/V13/ISSUE12/72

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Volume 13, ISSUE 12, Pages: 534 - 546

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International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
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DESIGNING HIGH-PERFORMANCE TMS ARCHITECTURES IN SUPPLY CHAIN MANAGEMENT: CHALLENGES AND BEST PRACTICES

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Abstract

Supply Chain Management nowadays necessitates integration of transportation businesses' company operations with technological innovations. Numerous software and information systems are available nowadays to automate logistical tasks, as is well known. Software packages for the Transportation Management System (TMS) are not yet fully and consistently categorised. In "Industry 4.0" their diversity matters. Navigating both established and new information systems and selecting the best one is challenging. The most significant TMS products are made to plan, coordinate, and record the fleet's operations. However, for a number of reasons, their actual use is often ineffectual. Implementing an information system often involves inadequate review of enterprise operations, standing in the marketplace, data movement analysis, employee evaluation, and decision-making mechanisms. The cause for this is the deficiency of information technology-based logistics management skills and, conversely, the often inadequate comprehension of transportation operations by IT engineers. Hence, a realistic strategy aligns strategic objectives, corporate procedures, supply chain administration, and information system logic. The use of the appropriate Zachman enterprise architecture framework as this strategy is covered in the article. The IT sector has long recognised this appropriate structure, which is easy to grasp. As a result, it seems suitable for small and medium-sized goods firms when used in the creation of the information supply chain management system in reality. It is well known that all transport businesses generally follow relatively similar business procedures.

Keywords: supply chain, strategic alignment, business structure, Zachman structure, and transportation management system

1.Introduction

In the current fast-moving and highly competitive business scenario, SCM has evolved to be a multi-dimensional and complex process, which involves instant data exchange, smooth system integration, and managing vast transactional as well as logistical information in real time. TMS is one of the major components of the modern SCM which is used to optimize goods movement, route management, carrier selection, and monitoring of delivery performance. A TMS architecture acts as a spine for efficiently managing transportation operations by reducing the costs and service level of the business [1]. Yet, its design has unique challenges while working on high-performance TMS architectures dealing with huge volumes of data, integrating with other systems within the supply chain, taking real-time decisions, and maintaining the reliability of systems under heavy loads. The demand for high-performance TMS solutions increases as businesses scale and their supply chains become more complex. Solutions are required to not only address current business requirements but also predict future growth and evolving logistics needs [2]. It is achieved through an in-depth understanding of the technical, operational, and strategic aspects involved in building a TMS architecture that efficiently manages transportation operations, reduces inefficiencies, and **provides critical insights for decision-making.**

Key Challenges in Designing High-Performance TMS Architectures:

Scalability: The TMS architecture needs to support ever-increasing volumes of data, transactions, and users as the business expands and new markets or regions are introduced.

Integration: To provide seamless end-to-end tracking of the supply chain, a TMS ought to be able to interact with other company software, including warehouse management software (WMS), enterprise resources planning (ERP), and client-facing portals.

Real-time Processing: Real-time data processing in supply chain logistics is of importance to ensure timely decision making, track shipments, and correct problems as they arise.

Data Accuracy and Consistency: Ensuring the quality, accuracy, and consistency of data across various systems and platforms will ensure that reliable decision making and operational efficiency are obtained.

Optimization: TMS solutions need to optimize routes, loads, and carrier selection for minimizing transportation costs and ensuring improved service levels.

Reliability and Uptime: Any downtime or failure in the TMS could bring operations to a halt with potential delays, financial loss, and unhappy customers.

User Experience: A high-performance TMS must provide an intuitive and responsive interface for all users, from logistics planners through to senior managers, making it possible for them to arrive at quick decisions [3-5].

However, ERP is an integrated solution that addresses a broad variety of management difficulties, even though some of the SCM application's capabilities match those of the ERP system (Fig. 1).

Figure 1: ERP system model

2. Using architectural principles to bridge the gap among supply chain management and the company

Since the 1970s, when computers emerged as one of the most crucial instruments for corporate administration, there has been much discussion about the disconnect between information technology and business demands [6,7]. A considerable amount of research is focused on examining how information technologies impact a company's development plan [8].

But since information and telecommunications technologies are developing so quickly, companies are taking longer to take advantage of the potential advantages that creative solutions may provide. IT is often seen by business executives as a miraculous instrument that can swiftly turn a hideous duckling into a gorgeous Swan. This means that the business's existing problems may be resolved instantly with the help of the most well-known (the the latest, the priciest, etc.) data system. At that moment, there is a dearth of knowledge about the fact that introducing innovative technology often necessitates altering the organisational layout, personnel attitudes, and business procedures of the company. As a result, we see an effort to combine outdated business concepts with the newest, most inventive IT solutions.

It goes without saying that we need an approach that would build the idea of the necessary information system while taking into account the viewpoints of all involved personnel and be based on strategic business objectives and business processes. The characteristics of the information system needed by every given business would be established based on this information model.

Enterprise architecture is a concept that views an organisation as a complex system with different components interacting with one another in accordance with predetermined rules in order to achieve certain business outcomes [9]. John Zachman is the creator of this strategy; he first presented the technique currently referred to as the Zachman Framework in the early 1990s. Approximately fifty frameworks, such as DoDAF, TOGAF, CIMOSA, and others, are available today to evaluate businesses with varying levels of detail [10]. It goes without saying that a thorough grasp of the organisational structure, business procedures, production chain operations, employee business roles, etc., is required in order to describe the architecture of an enterprise in a specific industry, such as a bank or a steel plant. Therefore, in order to create a model of the organisation, we must characterise and categorise each of the components of a business as a system, as well as the connections between them and the ways in which they interact.

Supply chain management (SCM) is one of the industries where the adoption of innovative IT solutions is now plagued by numerous significant difficulties due to the fact that this area of human knowledge is diverse and very complicated in and of itself, according to the analysis of literary sources. Knowledge of logistics theory isn't usually used in practical settings [11]. Therefore, we need a "road map" that allows managers, logisticians, and IT professionals to use common terms and be in a single semantic space to have a common project vision and consistently build up all future architecture levels. This will make it possible to quickly and effectively integrate information solutions with logistical operations when supply chain management is being implemented. First-step ontological business models feature identified business entities and their semantically dependent interaction. This business model undergoes further conversion into an information model with entities and links at the second level. Now, data structures, information flows, and information system table logical and physical architecture are complete. It is necessary to determine the kind of interaction that occurs between the various information systems of an organisation. Third, the application architecture—the software components of an information system—will be chosen. The technical environment, which includes hardware and network equipment, must next be created.

3. "Smart Logistical" Within The "Intellectuals Economics"

Technological advances has given rise to new theories on economic development. It is currently believed that the word "neo-industrialization" is more appropriate than the phrase "post-industrial civilisation" back when we were discussing it before. It represents a new phase in the integration of communication technologies and software products into industrial activity control. Terms like Industrie 4.0, Internet of Things (IoT), Smart Factory, Industrial Internet, Integrated Industry, Smart Industry, or Smart Manufacturing are used by the scientific and commercial communities [12]. The change of industrial processes is not the only way that "neo-industrialization" processes manifest themselves. It would be more pertinent to discuss the rise of the "intellectual economy" as a contemporary idea for structuring corporate operations. "Smart Logistics" receives a lot of attention in the suggestions for the execution of the strategic initiative

"Industry 4.0". The notion of the IoT first emerged in the USA in 1999, and the usage of RFID is an example of how this idea is being implemented.

Since the stability of the whole supply chain system is heavily dependent on the transportation stage, it is clear that specialised abilities, knowledge, and experience are needed for efficient cargo transportation management. These days, the logistics sector places a high strategic value on freight transit optimisation [13]. If the management of the supply chain We place special emphasis on the tasks related to the best possible planning, coordination, and management of transportation operations; there are many different contexts in which the "smart logistics" idea may be used. According to [14] they are often grouped together under the name "Transport Management System" (TMS).

However, uniform nomenclature in this field has not yet been decided. Terms like "Fleet Management Systems" (FMS) and "Intelligent Transport Systems" (ITS) are sometimes used, among others. On the one hand, the functional characteristics of the systems in use are the reason for the diversity of words. On the other hand, it is challenging to choose possible system users due to unclear categorisation and ambiguous nomenclature, since similar or identical names may refer to distinct hardware and software items. There are at least two factors that make this information especially significant. First, corporate management information systems, particularly those in the transportation industry, are increasingly built using the modular approach. Second, the adoption of "cloud computing" or the expansion of dispersed data processing scale are also significant factorsBoth of these circumstances significantly increase the error rate in the early phases of information system design when the system's client (usually collaborating with the system's possible a developer) establishes the goals, objectives, functions, construction, and phases associated with the prospective advancement of a transit operations oversight system—which, in fact, determines the system's architecture. Computer power, avionics and user-interface software make up transportation telematic systems.The phrase "Intelligent Transportation Systems" (ITS) is often used to refer to the traffic management system for automobiles that aims to maximise traffic capacity, decrease the chance of congestion on the road network, and increase safety. Because intelligent transportation systems optimise routes while taking traffic network congestion into account, they reduce accidents and the time it takes to deliver cargo and passengers, which improves transportation efficiency and fosters a favourable environment for logistics activities. In Russia, software packages that guarantee the computation of operating costs for the fleet of vehicles and document management are sometimes referred to as "Fleet Management Systems" (FMS). Higher functionality systems aid in resolving issues with technical maintenance and repair, tyre and fuel consumption, and transportation operation planning and accounting. In some instances, Russian information technology businesses provide "Fleet Management Systems," which are truly complicated systems. In addition to the aforementioned, they provide the modules that enable a variety of auxiliary tasks, such as processing delivery orders, arranging the best routes for both their own and borrowed cars, and managing the performance of the vehicles via satellite while they are

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being transported. The notion of "Fleet Management Systems" is often understood differently in Russia than in other nations. According to the FMS standard, Western commercial vehicle manufacturers outfit their cars with telemetry systems that periodically capture the vehicle's movement characteristics and information on the functionality of its primary components. The information gathered during telemetric observations is either sent to the control manager online or stored by the onboard computer.

In Russia, specialised Fuel Monitoring Systems (FMS) of all kinds installed on driven automobiles have grown in popularity. By its very nature, this device may be categorised as telemetric as it is mounted as a vehicle's on-board equipment and records fuel system operation data for later examination. The systems intended to monitor the execution of a predetermined goal for freight transportation may be separated from the satellite monitoring systems of vehicle movement that have more extensive capabilities. Unmanned vehicles and robotic transport systems are a unique class of systems that emerged as a result of information technologies' infiltration into the automotive industry and logistics. The main use for such structures is in enclosed areas, including warehouses, factories, or specifically marked roads. Unmanned wheeled transport vehicles and devices for land-based passenger or freight transportation, as well as air or sea-based automobiles for transport, are under development. In Russia [15] the term "Transportation Management System" (TMS) is used in a very wide meaning. The platform of the system in use; the ability to modify it while taking into account the characteristics of the business that will be using it; and the process for offering technical support while it is in use are the most crucial elements for the Russian software product market.

Typically, we identify whether a development is domestic or international from the outset. The decision between platform 1C and any other platform is made if the Russian provider is preferred. TMS systems may be categorised based on their field of use when it comes to controlling delivery by motor vehicles: Planning, organising, and accounting in the motor transport industry are examples of transportation activities management; planning and controlling the functioning of transport vehicles during cargo delivery is an example of transportation process implementation management. It is possible for local systems with different functions to be integrated with one another, utilised independently, or provided by the developer in a modular fashion. One important TMS type includes applications made to plan, coordinate, and manage the operations of transportation businesses. Their modular architecture may grow functional qualities to the appropriate limits and create a complicated TMS framework, relying on their transport activity. This idea is represented in the Capgemini Consulting functional model [16], which comprises operational, tactical, and strategic levels and repeats the TMS's main outlines as those of conventional SCM systems (Fig. 2). But according to [17], the scope of work is quite specialised and includes the following business processes:

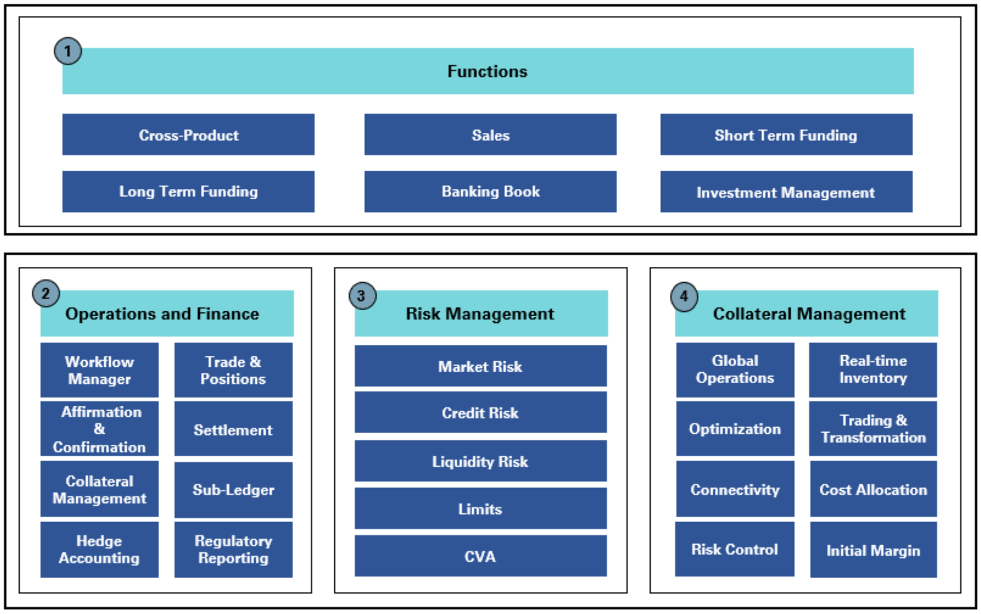

Figure 2: The TMS Functional Modules

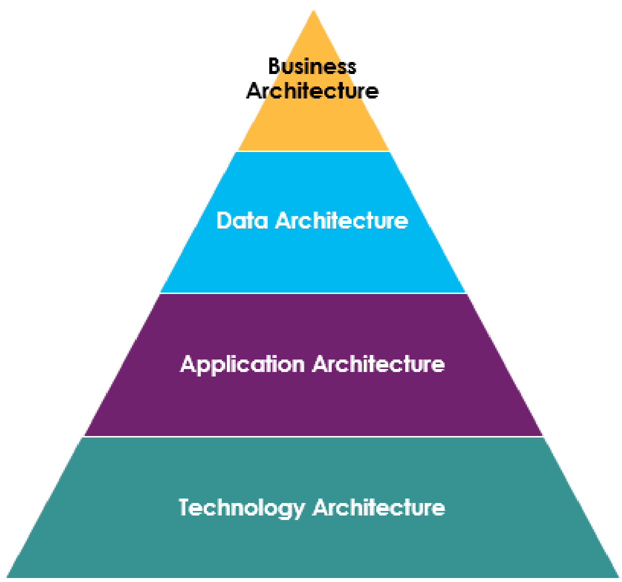

Figure 3: The Enterprise Architecture Model by John Zachman

Therefore, the study[18] focusses on the reality that, generally speaking, a large number of transportation-logistics companies worldwide that use different TMS frequently are unable to reduce the costs for vehicles with such applications and are unable to comprehend their structure. Additionally, they are unable to improve planning efficiency, management decision making, and business process transparency. Furthermore, the TMS often prioritises a certain market or sector and particular business procedures above others. Consequently, clients' demands are not entirely met. Additionally, a contemporary trend is the need to supply comprehensive business analytics capabilities along with a collection of "best practices" and case studies that many TMS providers are sometimes unable to give, in addition to systems designed to really automate operational operations. According to the work of [19] optimising a transport company's organisational pattern and enhancing the effectiveness of management decision-making in line with the organisation strategy should require the close integration of information technologies and logistic processes. In response, the TMS developers must put in more work to enhance their IT solutions in order to satisfy client demands. In contrast to operational planning, there has been little use of information technology for strategic planning of transportation-related operations in practice. Furthermore, it has been observed that a common cause of relatively poor TMS efficiency is the lack of standardisation in workflow procedures, which makes them difficult to access for online data visualisation decision-making. Furthermore, the facilities for vehicle monitoring are mostly used to determine the position without further investigation [20]. As one of the simplest models for the initial analysis of a logistics or transportation organization's construction before implementing TMS, we advise using Zachman's Guidelines (Fig. 3), modified to handle the respective duties of Freight Governance, Vehicle Business, and Driver managerial studies.

Zachman's Framework is a 6x6 table that, as is well known, includes the perspectives of the company's workers at different administrative levels on the following topics: "What?" "How?" "Where?" "Who?" "When?" "Why?" Six layers of the administrative hierarchy are represented figuratively by the framework: the planner, owner, designer, builder, subcontractor, and user. Our TMS "Autobase," which was created to handle car transport, was built using an architectural methodology based on the Zachman framework. The information system must be able to record heterogeneous fleets of cars, trucks, development, aerospace, farming, and other special-purpose machines. This is especially true for big mining, road construction, industrial, and airport projects. These businesses often have intricate, multi-level organisational structures with a vehicle pool for in-process tasks that are frequently scheduled according to different timetables. It should be mentioned that Russian law outlines the guidelines for maintaining records in situations involving the use of special purpose equipment and automobiles, where waybills are the primary document. The waybill displays the following parameters: flow, distance, hours worked, fuelling and remaining fuel. Additionally, the analytical formula determines the fuel consumption by considering the vehicle's age, load weight, operation modes, real running circumstances, and usage of a semitrailer. This is not the case in other nations, where the monitoring system is now often used to gather these parameters. Paper waybills must be kept on file in Russia, and management accounting should use the information from RFID and GPS/GSM monitoring devices.

Thus, the database of waybills for every automobile is used to determine the customer income, labour time, driver salaries, tyre wear, and preventative maintenance time. The TMS "Autobase" also does cost analysis, maintains maintenance and reserve vehicle data, displays over 300 reports, and uses OLAP applications. As a result, our TMS addresses vehicle management problems more thoroughly than freight management problems. For the Russian market for

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transport and logistics management information systems, this strategy is not entirely conventional since TMSs designed to control cargo flows are already widely used. This is because the management strategies used in the Russian transportation industry and the country's transportation laws don't always align with the latest international trends.

4. Performance Metrics and Benchmarking TMS Effectiveness

Transportation Management Systems (TMS) are nowadays a part and parcel of modern SCM. A TMS well-designed ensures efficient transportation operations, right from route optimization to the tracking of delivery, to enhance cost-effectiveness, service levels, and performance in the overall supply chain. However, to assess whether a TMS is truly effective, the business must turn its focus toward performance metrics and benchmarking. These practices allow organizations to assess if the system is aligned with their strategic objectives and operational needs. We will explore in this section the various performance metrics, methods of benchmarking, and how companies can use such tools to assess TMS effectiveness.

4.1 Key Performance Metrics for TMS Effectiveness

A set of metrics is important in terms of evaluation of the operational efficiency of a TMS. With these metrics, the firms can get insights regarding the operational performance of the system as well as points where there exists a scope for improvement. There are various key performance indicators that firms monitor about their TMS:

4.1.1 Transportation Costs

Transportation cost is the most critical measure of success for most organizations when using a TMS. These costs include shipping costs, fuel, labor, and other fees associated with a shipment. The main reason many organizations implement a TMS is to reduce transportation cost without compromising service levels. A TMS can directly lead to these savings through route optimization, better load planning, and improvement in carrier management. Monitoring key components of transportation cost includes:

Freight Costs: Total freight cost paid to the carrier for transporting goods.

Fuel Cost: Fuel efficiency is also one of the most relevant transportation costs. TMS solutions assist in minimizing the unnecessary fuel consumption while improving routes and minimizing the idle time.

Carrier Performance: Comparing the cost and effectiveness of every carrier, including all late delivery penalties, will lead to optimizing carrier selection for a reduction in cost.

Accessorial Costs: Surcharges on fuel, stop-off charges, and detention charges all need to be tracked to ensure efficient cost management.

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4.1.2. On-Time Delivery

On-time delivery is one of the critical metrics for customer satisfaction and overall service performance. TMS systems track shipments in real time, providing a clear view of delivery schedules and expected times of arrival. The tracking of on-time delivery performance enables organizations to evaluate the accuracy of their TMS's route planning, scheduling, and real-time updates. A high on-time delivery rate is often related to better operational efficiency, fewer customer complaints, and lower operational costs because of fewer delays.

4.1.3 Carrier Performance

Carrier performance metrics give the insight into the efficiency of transportation providers. TMS platforms often track the performance of different carriers across several factors:

On-time Delivery Rate: The percentage of shipments delivered on time by a particular carrier.

Cost Efficiency: Comparing the cost per mile or per load for each carrier.

Damage Rate: The number of times a carrier damages goods in transit.

Compliance and Regulations: Monitoring the carrier's compliance with the regulations and safety standards can be included in performance reviews.

4.1.4. Shipment Visibility

Shipment visibility measures the capability to track and monitor shipment status in real time. One of the key advantages of modern TMS solutions is the ability to provide visibility all along the transportation process, from origin to final destination. High visibility helps companies proactively identify potential delays, reduce supply chain risks, and enhance customer communication. Metrics related to shipment visibility include:

Real-time Tracking Updates: How often and how detailed updates on status are made to stakeholders.

Time to Alert for Delays: In what time span does the system alert stakeholders in case delays or disruptions arise.

End-to-End Visibility: In what extent does a TMS offer complete tracking starting from point A to point B.

4.1.5. Inventory Turnover and Stockouts

Although transportation metrics revolve around the transport of goods, inventory management is also an important variable, which is impacted by the TMS. With efficient transportation planning, stockouts and, by extension, inventory turnover are optimized. A TMS enables a company to control the speed at which goods move from the warehouse to the customer, thereby reducing the probability of excess stock and lowering the effects of stockouts. Tracking metrics on inventory turnover and stockouts keeps organizations with the right amount of inventory and keeps transportation costs low.

Table 1: Effectiveness of a TMS

Performance Metric	Description	Key Indicators/Elements
Transportation Costs	Measures the overall cost-effectiveness of transportation processes, helping to identify cost-saving opportunities.	- Freight Costs (carrier payments) - Fuel Costs (efficiency, consumption) - Carrier Performance - Accessorial Costs (surcharges, penalties)
On-Time Delivery	Tracks the efficiency of delivery timelines, crucial for customer satisfaction and operational efficiency.	- On-Time Delivery Rate - Delivery Schedule Accuracy
Carrier Performance	Evaluates how well transportation providers are performing in terms of cost, efficiency, and reliability.	- On-time Delivery Rate - Cost Efficiency (per mile/load) - Damage Rate - Compliance & Regulations
Shipment Visibility	Assesses the ability to track and monitor shipments in real time, providing better decision-making capabilities and customer communication.	- Real-time Tracking Updates - Time to Alert for Delays - End-to-End Visibility
Inventory Turnover and Stockouts	Focuses on optimizing inventory management through transportation efficiency, reducing excess stock and mitigating stockouts.	- Inventory Turnover Rate - Stockout Rate (how often items run out of stock)

The table 1 depicts metrics that are essential for evaluating the effectiveness of a TMS and ensuring that it aligns with organizational goals for efficiency, cost reduction, and customer satisfaction.

4. Conclusion

The use of information technology in logistics transportation assistance is the subject of this essay. The "intellectual economy" and "neoindustrialization" processes are causing issues, and it is within this context that the idea of "smart logistics" is being used. prospective errors might include misusing specialised language and creating a communication barrier between software developers and prospective users. In this sense, choosing software is often done without carefully weighing the specifics of transportation operations and first determining the functional components that are required. By classifying information systems, the article makes it possible to choose software that reduces the possibility of mistakes while simultaneously meeting the objectives of strategic, tactical, and operational management. Examples seem to suggest that using an architectural approach when implementing TMS facilitates agreement with managers at various levels of the hierarchy, the gradual development of the potential system's functionality, and the establishment of the closest possible collaboration between transportation specialists and IT experts. With proper consideration for all commercial, human, technical, and other aspects of their operations, the strategy that has been put out here is rather easy to apply and execute for small, medium, and big businesses.

Using this methodology, we created the TMS "Autobase," a complete fleet management system that is now used by a number of businesses, including very big manufacturing facilities. In fact, our technology enables efficient management of the transportation process and has included the best practices of several Russian logistics and transportation businesses.

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