

Article

The Significance of IoT Technology in Improving Logistical Processes and Enhancing Competitiveness: A Case Study on the World's and Slovakia's Wood-Processing Enterprises

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Received: 25 August 2020; Accepted: 18 September 2020; Published: 21 September 2020



Abstract: The wood-processing industry currently does not sufficiently use modern technologies, unlike the automotive sector. The primary motive for writing this article was in cooperation with a Slovak wood processing company, which wanted to improve its logistics processes and increase competitiveness in the wood processing sector through the implementation of new technologies. The aim of this article was to identify the positives and limitations of the implementation of Internet of Things (IoT) technology into the wood processing industry, based on a secondary analysis of case studies and the best practice of American wood processing companies such as West Fraser Timber in Canada, and Weyerhaeuser in the USA. The selection of case studies was conditional on criteria of time relevance, size of the sawmills, and production volume in m³. These conditional criteria reflected the conditions for the introduction of similar concepts for wood-processing enterprises in Slovakia. The implementation of the IoT can reduce operating costs by up to 20%, increase added value for customers, and collect real-time data that can serve as the basis for support of management and decision-making at the operational, tactical, and strategic levels. In addition to the secondary analysis, methods of comparison of global wood processing companies, synthesis of knowledge, and summarization of positives and limitations of IoT implementation or deduction were used to reach our conclusions. The results were used as the basis for the design of a general model for the implementation of IoT technology for Slovak wood processing enterprises. This model may represent best practice for the selected locality and industry. The implications and verification of the designed model in practice will form part of other research activities, already underway in the form of a primary survey.

Keywords: management; logistics; processes; Industry 4.0; Internet of Things; information; communication technology

1. Introduction

The concept of logistics comes from military preparations and tactics, which highlight the importance of optimal supply. Historical records, documents, and files describe the progress of processes underlying the current graphical recording of activities through flowcharts. An associated effect is the ability to learn from past errors. Managers receive relevant information from regular audit evaluation of logistics processes, which they use in management and decision-making at all business levels. The combination of field distributions and information and communication technologies (ICT) reflects the importance of information management. The four waves of the industrial revolution have also influenced logistics processes. In the early 21st century, with the introduction of robotisation,

ICT elements were also implemented in material flow transport activities, along with the trend of the Internet of Things. Future trends, such as digitisation, localisation, “green” warehouses, artificial intelligence, custom warehouse management systems (WMS), radio frequency identification (RFID), and quick response codes (QR) may reduce operating costs and support the competitiveness of companies. The importance of using “smart” devices is reflected in the concept of developing space technologies in logistics, AGV (Automated Guided Vehicle) trucks, trackers, mobile business intelligence, and IoT integration with Blockchain or RFID. By 2020, surveys have forecast a threefold increase in the use of the Internet of Things in all areas of life, leisure, and operational activities. This includes the implementation of the IoT in the logistics processes of wood processing companies. In this way, it could be possible to reduce the strong influence of automotive industries, which alone cannot function and thrive continuously without thorough and efficient distribution. The IoT is also a “gateway” to the implementation and effective use of Industry 4.0 (I4.0), so it is an essential part of it. In addition to the benefits, the introduction of new creative ideas and applications also carries risks and limitations (low security, hacking attacks, theft of confidential data, storage of big data, etc.). Wood processing companies that are actively involved in developing new trends and implementing IoT technologies will strengthen their current market position in the future and provide their competitors with a guide to best practices for success.

2. Literature Review

Planning, organising, management, and control functions represent the essential management activities. Managers perform roles around running the enterprise processes, applying their theoretical knowledge, practical experience, and innate or acquired predispositions. In 1961, Taylor considered management to be a way of telling someone what to do and leading the person to do it to the best of their ability at the lowest expense [1]. In 2019, Kaehler and Grundei claimed that management affects resources, production, and the market, and participates in determining and achieving the enterprise’s goals through various partaking players [2]. Distinguished theorists who have dealt with research into management have specified fundamental elements of management (its goal, people, and managerial functions). Drucker avoided a direct definition of management and preferred a comparison to a multipurpose body [3]. The unifying factors of contemporary management are people and processes, including logic. Operations management and logistic management are remarkably close—ensuring effective transport operations which will meet customers’ preferences [4,5]. Operations management involves integrated logistics operations which ensure the functioning of the marketing, financial, and sales departments [6,7]. An enterprise uses three basic types of logistics depending on the life cycle of a product: supplying (procurement), manufacturing, and distribution logistics. Supplying (macro) logistics deal with the management of the supply chain and reflect a relationship between a distributor and the enterprise. Its functions include ensuring the optimum amount of input material for the needs of production. It is essential to compare the factors of time, quality, and price. Manufacturing (micro) logistics ensure the receipt, storage, and manipulation of materials, shipping, and operations of unfinished, ready-made, and semi-finished products. Distribution (marketing, macro) logistics control the delivery of products to the end customer for his or her consumption, or to other enterprises for further processing [8]. Auditing is useful for identifying and improving the current state of logistical processes.

2.1. Logistics Auditing and Diagnostics of Logistical Processes

The first audit phase is to identify a mission, current goals, and vision of the business entity. An audit of existing systems and ongoing activities takes place with a three-step method [9]:

1. Descriptive: Acquiring information about the business strategy, product portfolio, materials, and information flows.
2. Diagnostics: Examining the current state of logistics processes, interfaces, and indicators of process management.

3. Recommendations: Offering suggestions for eliminating gaps.

The modern (internal and external) logistics audit involves instructions on how to implement a digital concept of Logistics 4.0 into current manual distribution processes [10]. Inputs transformed into outputs have a specific value delineation for the process (its start and end). The processes can be categorised into [11]:

- Control processes: at the top-level, planning, strategies, visions, a mission, goals, coordination, and synchronisation of main and service activities.
- Transformation processes: in manufacturing, given by the product.
- Service activities: including logistics, maintenance, and book-keeping.

The mapping of processes reveals deficiencies and duplications in the form of complexities or interfaces. A visual representation in the form of flow charts shows the flow of materials, and reveals possibilities for improvement. Procurement (supplying), storage, distribution, and reverse logistical activities are among the primary logistical processes ensuring the operation of the enterprise.

2.2. The Course of Logistics and Logistical Processes

Analytical research by the Czech specialist journal Logistics predicted a significant impact of the following digital trends in Table 1; Table 2, between 2018 and 2022.

Table 1. Summary of predicted trends of various logistics authors: first part.

Author(s)	Predicted Trend (2018–2020)
Dobiáš [12]	Growth of e-commerce affects logistical innovations, giving rise to the need for adjustable warehouses.
Toman [13,14]	Production based on customer orders faces a challenge of the integration of logistics with the procurement department.
Novotný [15,16]	Digitalisation and automation in three areas (quality, economy, HSE (Health and Safety Executive)).
Novotný [17,18]	Establishment of “green” logistical centres for environmental protection.
Toman [19,20]	Introduction of electric cars.
Holubcik [21]	Automatic localisation in warehouses using sensors.
Toman [22–25]	Support of distribution innovations in warehouses: dascher enterprise has created a warehouse based on a virtual reality where they monitor the consumption of assets using bulk QR (Quick Response) codes. The example from FM logistic CZ (Czech Republic). RFID (Near Field Communication) readers and terminals.
Holubcik, Falat [26]	Robotisation: Global growth is forecast to occur by 2025. For illustration, it includes drones, agvs (autonomous vehicles), igvs (intelligent vehicles), and awrs (autonomous warehouse robots). Cobots: for collaboration and stock-taking using RFID technologies.
Novotný [27–29]	Data are considered the “power fuel” of the economy: Paul Noford (Zebra Representative). Communication between the warehouse and production will take place through iiot tags from Openmatics developers. The trend for re-engineering the current processes through Anasoft artificial intelligence supports the development of business digitalisation.

The benefits of trends outweigh their shortcomings and risks. Only those who monitor the influences of the external environment and know their own internal processes can achieve a competitive advantage.

Table 2. Summary of predicted trends of various logistics authors: second part.

Author(s)	Predicted Trend (2018–2020)
Toman [30]	Control and monitoring of the temperature, humidity, and other measurable indicators of the environment is becoming a key element of effective storage.
Toman [31]	Focus on employee comfort at work: machines and equipment of higher quality, suspension tires on fork-lift trucks. For example, Toyota uses SolidAir.
Kladiva [32]	A new design of lorries with a wider cabin will save costs. Implementation is going to occur in 2021.
Kotora [33]	IoT: Globally, approximately 14.2 billion smart devices are currently in use, and in 2025, the number will rise to 25 billion. Logistics is implementing sensors, and the information technology (IT) infrastructure of current systems and processes is changing.
Novotný [34,35]	Augmented reality: Glasses for hands-free scanning are popular.
Novotný [27]	The visualisation makes it easier to dispatch and pack orders, resulting in fast management of stock.
Novotný [28]	Artificial intelligence (AI), machine learning and virtual assistants, chatbots: Gartner analysts forecast an increase from 25% to 37% (2020). Digital twin: research predicts 20 billion sensors (2020).
Toman [36]	Data protection is necessary through new-generation firewalls as threats and cybersecurity have been underrated. According to ENISA research, 40% of respondents do not test the reliability of systems.
Novotný [37,38]	Care for and cleanliness of fork-lift trucks will be ensured by autonomously controlled washrooms which will arrive directly at a customer's premises.
Veber et al. [39]	Forestry uses so-called trackers actively: small devices placed on trees which monitor the felling of trees and alert employees to illegal activities in the Amazon rainforest.
Toman [40]	Energy is reused by Dasher Li-on batteries in enterprises, replacing accumulators in 2022.
Toman [41]	Implementation of trends, such as Cloud and Blockchain: The trend is toward reducing the number of printed documents and simplifying paperwork.
Skoták [42]	The open-source economic platform which is used nowadays is called Hyperledger Fabric by IBM.
Štěpánek [43]	Enterprises are creating their own WMS (Warehouse Management System) systems using HMI (Human Machine Interface) interfaces (human–PC interaction).
Toman [44]	Development of 5G mobile networks and standardization.
Novotný [45]	Monitoring equipment, focus on reverse logistics.
Otto, Vaculík [46–48]	Interoperability, customer relationship management (CRM) integration, Industry 4.0, and Big Data analytics are the challenges.
Toman [49,50]	Enterprises are affected by the trend of prescriptive analytics, giving answers to the questions of what, when, and why something has happened, using historical data.
Voigts [51]	Efficient servicing of vehicles with the T-Stream platform by Toyota Material Handling. IoT improves the quality of HSE.
	Space technologies shift to the area of logistics, as claimed by Tomáš Rousek, NASA Member.

2.3. Tendencies in Logistics and Logistical Processes

The implementation of software technologies in an enterprise affects the products, services, and overall performance. Simultaneously, it offers a possibility to attract new investments, reduce costs and ensure new income sources, and eliminate risks through analysis. Manufacturing activities mostly fulfil the primary function. In the 21st century, innovations began to focus on logistical operations and their harmonisation with procurement and production. Elements of 3D printers, autonomous cars, warehouse information systems, drones, and customer behaviour research through connected shopping baskets or robotic workplaces in Denmark and Paris (Charles de Gaulle Airport) have significantly changed views on Logistics 4.0 [39,52,53].

Global research in the implementation of the Internet of Things in logistics predicted that this innovation would be used by three times more customers in 2020 than in 2015. This effect would be manifested itself as an increase in incomes (2015–2020) of USD 2 billion in enterprise distribution [54]. An enterprise can introduce technologies for complex supply chain management. The transparency of endpoints increases with RFID thanks to an early warning system. The monitoring of an external supplier's logistical operations is a benefit. GPS (Global Positioning System) and ELD (Electronic logging devices—a system for recording measured values) ensure fleet management. These technologies make it possible to predict fuel consumption, localise a vehicle, identify its current speed, and plan a route with the lowest costs (CPM, Critical Path Method). Culminated historical data make it possible to learn from past mistakes [55–57]. Storage in the IoT ensures automatic door opening, and sensors installed on pallets and fork-lift trucks alert workers to unusual situations, increasing their safety and reducing risks at work. QR codes can be used for monitoring the current state of stock (without manual calculations) and prognosticate on the future (arising from demand and an offer). The effect is energy savings, which may result in the status of “green logistics”. Favourable conditions for implementing the IoT in logistics include [58]:

- The sector is the first one applying novelties.
- Development of 5G networks.
- Better available components.
- The use of big data.
- More demands from customers, generating a sizable amount of data through applications daily.

An example of the successful and efficient implementation of ICTs in logistics is the German Alethia project, which is behind the emergence of a Wi-Fi system which implemented pallet sensors able to predict the fall of goods, and measure temperature, quantity, and other factors. The result was increased safety and health protection at work, a lower number of injuries, and availability of real-time data. [58] For the trouble-free implementation of the IoT in production and logistic processes in an enterprise, it is necessary [46,59]:

- To ensure interoperability.
- To ensure confidentiality, availability, and integrity of data transferred through the network (internally and externally).
- To support standardisation and acquire knowledge from reference models (best practices).
- Change employees' thinking and motivate them to reorganise processes.

Transparency, prediction, control, monitoring, management, and decision-making support are crucial elements which positively affect not only managerial activities and functions, but also the operating activity of the enterprise as a whole. The use of space technologies, AGVs, monitoring equipment (so-called trackers), mobile business intelligence technologies, the IoT, Blockchain, and RFID has immense significance for distribution.

2.3.1. Space Technologies in Logistics

Research programmes focused on the implementation of satellite navigation technologies in public transport are currently being conducted in Prague (as part of the Horizon 2020 Project). In the opinion of the Representative of the Ministry of Transport, “customers who use GPS navigation or shop online through e-commerce subconsciously use technologies from space, which ensure efficient and cheap logistics through satellites,” [60]. The market for transport apps has increased by 10% annually. The best-known space technologies are Galileo and EGNOS (European Geostationary Navigation Overlay Service) [60]. These days, more than 100 million devices use Galileo. The satellites can navigate aeroplanes, buses, cars, and the whole urban infrastructure using GPS. EGNOS contains a detailed background for the Galileo system, and comprises the so-called “networked European technical centres”. “Location-Based Services” are formed by the connection of space technology and

logistics. A client will see necessary information on their mobile phone or tablet apps, such as distance from a particular object, trolley bus departures, shopping mall opening hours, and others. The effect is sufficient information, transport monitoring, early warning systems, lower transport costs, selection of suitable routes, and mobility synchronisation [60].

2.3.2. AGV Vehicles

In 1953, Barrett Electronics developed and marketed the first autonomous vehicle, which works on the principle of movement utilising magnetic strips. Currently, this warehouse technology is provided, for example, by Danish supplier Mobile Industrial Robots. The vehicles have been modernised with new 3D cameras and laser scanners. Satisfied customers include Škoda Auto (in cooperation with CEIT), Visteon, and Continental. The result is simple navigation in space, fewer mistakes, fewer injuries, automation, and control through RFID [15–18,27–29,34,35,37,38,45].

2.3.3. Trackers

Three technologies monitor materials, products, vehicles, and other things, and microtags create unique monitoring and access codes using colourful plastic microparticles. Identification is made by reading a magnetic and fluorescent layer [61]. The US Forest Service has been monitoring logging since 1988 with two chemical trackers that only a unique laboratory or the given forest can decipher. They mark the trees to be cut down and transported to a sawmill [61]. However, the monitoring marks are also useful for revealing illegal logging. A suitable practical example is a case between Greenpeace and the Amazon Rainforest Administration from the 20th century, involving placing marks using ultraviolet paint to monitor the felling of round timber more easily. These operations have undergone standardisation and gained a certificate from the Brazilian Forest Service [61]. Genetic imprints verify the product according to a left DNA trace. An increase in the use of this technology has been forecasted in the next 3–10 years [61].

2.3.4. Integration of the IoT and Blockchain, Mobile Business Intelligence

Blockchain technology controls a shift from manually performed processes to automated ones (IoT). The effect of this connection is trustworthy, reliable, and shared information, enhancing IoT safety in logistics [62]. Fog Computing is a new interaction layer between Cloud computing and IoT devices—so-called hybrid access. The Cloud is moving closer to the edge. The interaction of two IoTs allows for offline work and fast and relatively safe communication. The IoT and Blockchain make it possible to save unchangeable data into records on the fly [62].

Medium-sized and large enterprises currently employ analytical and planning techniques, methods, and concepts, which is called business intelligence. Their functionality (dashboarding, Key Performance Indicators and notifications) has also been transferred into mobile devices. When the customer opens an app to obtain the relevant information, the enterprise works based on the “pull” principle. Otherwise, the “push” principle applies—the enterprise verifies whether published data are correct and up to date. GDPR (General Data Protection Regulation) is a critical element. Therefore, mobile BI (Business Intelligence) must have secure access (encryption, authorisation). The Forrester company’s research has revealed that sharing and generating data through mobile apps is not a problem for up to 57% of respondents. The condition was the maximum reliability and trustworthiness of a web page, about which they spread positive reviews subsequently [44,48]. In general, the more sensitive the information published on the internet, the higher the level of protection required.

2.3.5. RFID Technology

One-dimensional EAN (European Article Number) codes are being replaced by QR and RFID codes, which work through tags and readers, in the form of a write-once-and-read-many record and with wireless technology (Wi-Fi). The technology is most frequently used in logistics, manufacturing,

and retail. The highest types of frequencies localise fleets, cars, persons, or railway carriages. Frequency bands include [63]:

- Low, LF (Low Frequency): access, marking and protection of assets, animals (100–135 kHz).
- High, HF (High Frequency): logistics, retail, personal access (13.56 MHz).
- Ultrahigh, UHF (Ultrahigh Frequency): transport, monitoring of assets from a significant distance, pallets.

Tags, readers, a database server, and a storage site form the basis of RFID technology components. In addition to RFID, the augmented-reality Pick-by-Vision principle is applied to ship stock from a warehouse [8]. A tag with a chip and aerial, along with a reader, form an RF subsystem (Wi-Fi transactions of data between devices, where the reader emits electromagnetic energy to read a tag). Network tags monitor the movement of materials and localise their exact position. Data are saved on a database server, which processes them in the form of analyses [64]. The enterprise can also store the data at a central storage site, which it can access from multiple devices (a Cloud server). The end-user can display necessary analyses and operational data through a smart device, including a tablet, smartphone, and others (see Figure 1).

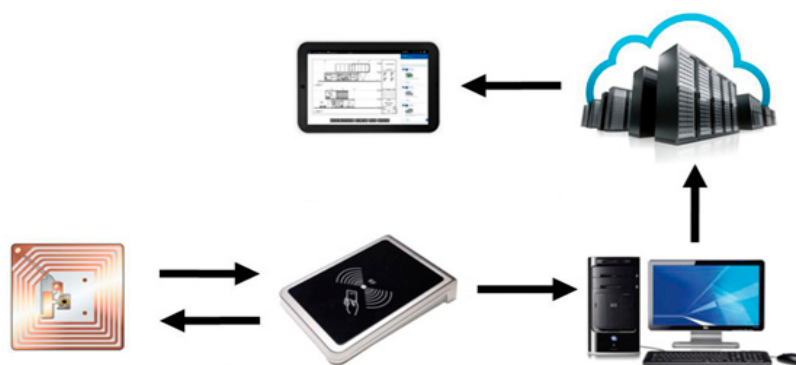


Figure 1. Components of RFID technology [65].

An employee receives the necessary information about the storing of materials, the number of pieces, and the order status through smart glasses. The functions include EAN and QR code scanning, real-time visualisation, stock identification, and WMS support [8].

3. Materials and Methods

The examination of the importance of introducing the IoT into wood processing companies was carried out through a secondary analysis of best world practice (case studies). The selection of case studies was conditional on time relevance; the data were not older than 2015. In this way, it was possible to focus more intensively on modern technologies, the development of which takes place in a dynamic environment and is subject to constant change. The subject of the analysis was focused on the identification of advantages and limitations of IoT implementation in the logistics area of wood processing companies, and the influence of the IoT on management. Keywords consisted of terms such as Internet of Things in the wood processing industry, logistics, logistics processes, and so forth. To identify the relevant data, the following research question was defined: “What technologies are used by global and domestic producers in the wood processing industry in the field of logistics, and what effects does this have?” The problem of interest is high logistical and operational costs and an insufficient competitiveness in the wood processing market. Alternative solutions will apply to countries that meet the criteria of a sufficient number of sawmills, sufficient production in m³, and the existence of top wood processing industries for case study purposes. The case studies were searched for in available scientific databases, such as the Web of Science and Scopus. The content of the case studies included cost reductions, optimal deliveries, real-time data, management and decision support,

higher added value, and associated profit growth. Best practice was selected on the basis of the results of the consultants. North America, China, and Europe are among the key producers in the wood processing industry, according to the “Global Sawmill Market Report 2017–2022” survey. Hypotheses and testing methods were not part of the articles, because the articles’ purpose was to undertake a case report.

The current state of the international wood market has been negatively affected by the US and China trade war. The US has introduced 25% higher tariffs on wood to protect domestic producers. Globally, wood production is expected to increase from -0.7% to 1.5% in the short term, and consumption from -0.8% to 1.4% (range 1990–2005 vs. 2005–2020). The prediction for 2030 points to the maintenance of current positive values. The increase in wood production will concern South America and Russia, although the wood processing from tropical forests has a negative impact on consumers and gradually reduces demand for these products [66,67]. The wood processing industry is characterised by lower profit margins than other sectors of industry. The main element of competitiveness in the wood processing industry is the reduction in operating costs. A solution is offered here by the implementation of the IoT in the form of “Smart Connected” innovations (better quality wood, and optimal logistics and production processes).

From the above criteria, two sawmills in North America were selected as the examples of best practice: West Fraser Timber in Canada and Weyerhaeuser in the USA. The same criteria (production volume, number of saws, quantitative effects) were also used in the selection of a best practice example in Slovakia: Rettenmeier Tatra Timber. This company reached the leading runs in the database of sawmills in this country. Primary data were collected by performing a logistical audit, according to the procedure in Chapter 2.1, considering the conditions of the Slovak wood processing company. The company did not want to disclose personal data resulting from Audi and their activities. The data were generalized in the form of an implementation model (Chapter 5), which will serve as a model for the effective implementation of the Internet of Things technology for Slovak wood processing companies.

In addition to the secondary analysis and the results of the logistic audit, this article also used synthesis and induction methods to draw conclusions, and deduction and analogy to create its own model in Chapter 5, including a summary of the lessons learned in determining the benefits and limitations associated with the introduction of the IoT. The practical implementation of the model into Slovak companies will be the subject of further research in the future, as well as assessment of the quantitative and qualitative effects of this implementation.

4. Results

4.1. North America

We gathered data on the present situation from the Sawmill Database (Table 3). According to the database, North America is a leading global producer in the wood-processing industry. The following table shows the information on best practices.

Table 3. Selection criteria for choosing relevant case studies [68].

Criteria			
State	Number of Sawmills	Sawn Wood Production (m ³)	Top Enterprise
USA	227	6,449,000	Weyerhaeuser
Canada	225	8,460,000	West Fraser Timber Co Ltd.

The absolute majority (approximately 70%) of North America is composed of forest, which is an essential source of round timber. Even though working at a sawmill is dangerous, enterprises employ more than 953,000 people. This industrial sector notably helps reduce unemployment. There is a year-on-year increase in the US wood-processing industry (2013–2018) of 3.3%. Canadian sawmills produce 23% of sawn wood annually [69]. Figure 2 shows the state of the current situation. The sawn

wood price index has high volatility. It grew from 108.4 to 110.17 over the April–May period in 2019 [44]. The reason for this lies in the increase in demand for wood-processing products, and consumers' interest making it possible to raise the prices of the products.

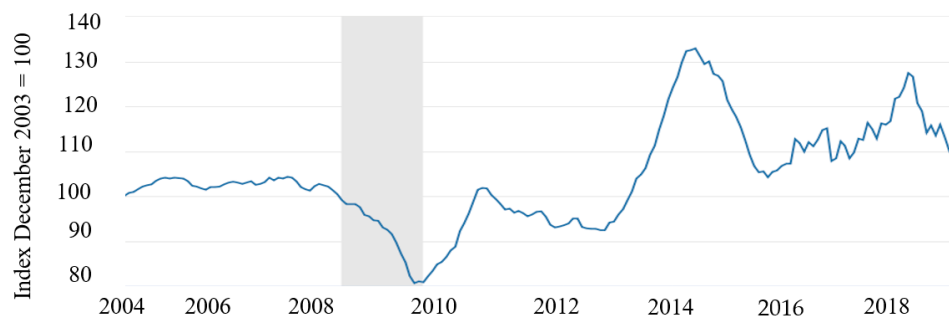


Figure 2. Sawn wood price index in the wood-processing industry (2004–2019) [70].

Fierce competition, as well as the 2008–2010 financial crisis, represent the external factors that kept the value of the index down in the industry.

4.1.1. Case Study on West Fraser Timber Co Ltd.

This enterprise dates back to 1955. In 2019, it received Canada's Best Employers Award, according to its Forbes ranking [71]. This Canadian sawn wood producer developed the BuildPlus app, which makes it possible for customers to monitor their orders, including preparation and distribution, in real-time [72].

Road transport prevails in logistics. Up to 80% of the wood is distributed by lorries with autonomous fastenings. This results in a minimum loss of cargo, minimum waste, and optimum delivery times [73]. However, currently, the price of sawn wood is too high (see Figure 2) because of new tariffs and increased demand from American citizens for wood products in the construction sector. The fact that overcrowded railways transport up to 20% of sawn wood from West Fraser exerts an unfavorable effect, because the supplies are often not delivered in time [74].

4.1.2. Case Study on Weyerhaeuser

The American Weyerhaeuser enterprise is a leader in the area of round timber processing. Its origins date back to the 20th century (1900). In Q1 2019, it yielded a net profit of USD 80 billion [75]. Table 4 shows the focus placed on innovative technologies and the IoT, primarily in logistics and secondly in manufacturing. Innovating internal processing by implementing new technologies is the critical value of the enterprise. The effect is an added value for the customer, as well as in CRM, management, and decision-making support, making the enterprise a leader in the wood-processing industry. Simultaneously, its apps are CSFs (Critical Success Factors). Weyerhaeuser ranked 901st in the Forbes Global 2000 World's Largest Companies 2019 [73,76].

The IoT ensures real-time data collection from devices, storage through a Cloud storage site, access through Cloud computing, an internal infrastructure change, the use of data centres, optimisation of logistical operation, and digitalisation [71].

Mobile apps which collect data directly in the forest are of significant benefit. They simplify paperwork and documentation activities. IoT support is provided through the acquisition with Plum Creek (2016), by introducing Microsoft technologies and by organising Gartner CIO events [77].

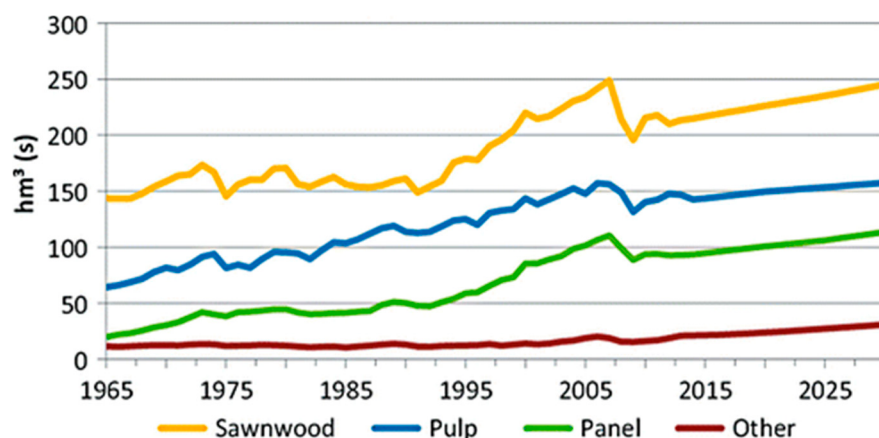
Table 4. Weyerhaeuser software solutions in logistics and manufacturing [71].

Weyerhaeuser Technologies		
Area	Description	Benefit
Logistics		
Stellar	Sawn wood storage, manipulation	Compatibility with other Weyerhaeuser systems, effective management
Installation		
Document Library App	Access to saved data, installation manuals in the online and offline regime, sharing, grouping of API (Application Programming Interface) libraries	Real-time data, management and decision-making support, simple installation, synchronised with Weyerhaeuser systems, CRM support
Revit Downloads	Easy installation of logs on construction sites, 3D visualisation for architects, functions available through the Cloud	Performance, reliability, user-friendly usage, added value for the customer
Forte	Automatic construction calculations (depth, load degree, permitted load-bearing capacity)	Operative decision-making support
Modelling		
AUTOCAD, Sketchup	3D view of construction elements	Simple views synchronised with the Trimble 3D Warehouse system

4.2. Slovakia

Forestry contributes to environmental protection as the wood binds carbon, preventing global warming. The wood-processing industry has a long tradition in Slovakia. These days, it employs 40,000 to 100,000 people. Wood products earn approximately EUR 3 billion annually, affecting the GDP positively [78,79]. Exhibitions, such as LIGNUMEXPO, Les, and Agrokomplex in Nitra, present and introduce modern trends. In 2018, their central topic focused on the impact of robotisation, automation, and digitalisation on wood-processing enterprises [80]. According to the Wood Processors Association, the present situation in the sector is not optimal. Forestry creates vacant jobs for citizens with a lower education, creating an added economic value. Association General Manager Peter Zemanik claims: “For the Slovak wood-processing industry to develop sustainably, the government should avoid interfering in the management and decision-making of state forests” [80]. The unused potential of lumbering and wood production, the unstable situation, and lower competitiveness result in interference compared to international competitors [81,82].

Forecasts predict a slight increase in and a subsequent stabilisation of the values of sawn wood, wood pulp and wooden panel consumption by 2025. Volatility will stabilise, and the highest demand will be for sawn wood (Figure 3).

**Figure 3.** Overall wood consumption according to product groups in EU 28 [83].

Case Study on Rettenmeier Tatra Timber, s. r. o.

Rettenmeier Tatra Timber, s. r. o., which is located in Liptovský Hrádok, is the most significant domestic sawn wood producer. Its localisation is strategically beneficial, covering the leading network of suppliers between Žilina and Prešov [84]. According to the international Sawmill Database, up to 440,000 m³ of sawn wood is produced annually. The impact of implementing technologies for reducing operational expenses to maintain the enterprise's competitiveness was the criterion examined in the case study. The solution is a regular audit assessment of energy consumption, the establishment of a partnership with the ENVIROS enterprise, implementation of sensors for the monitoring of movement to use energy more efficiently, and environmental protection through energy management and the enterprise's biopower plant [85]. The enterprise solved a problem with the manipulation of wooden panels by implementing new technology—the eT-Gripper automatically controlled suction boxes. They solved the problem of an insufficient number of driers by enhancing existing processes with robotisation, sensors, and digitalisation [86]. The result is predictive maintenance, simple use, costs reduced by 30%, life cycle assessment of material flows, and growth of the added value for the customer. Their profit increased by 150% compared to 2018 [87,88].

4.3. Case Studies on the Implementation of IoT Elements in Wood-Processing Enterprises

Sensors situated directly in the forest can collect real-time data, and they have contributed to the digitalisation of the transport of beechwood for processing in the Finish Metsäteho enterprise. Estonian wood-processing enterprises also use the Maestro system (Supply Chain Management in Italy). This results in predictive and remote maintenance, monitoring, e-delivery notes, expert analyses of forest surfaces, and risk elimination [89]. The Qulix system can measure the production processes of round timber processing. The purpose of a server which receives data from the sensors is to calculate the OEE (Overall Equipment Effectiveness). The effect is finding a reason for downtime. This saves USD 1 every minute, which represents USD 60 per hour of production or logistical process [89].

An Example of a Wood Monitoring Process with IoT Sensors: A Sawmill in Southern Italy, Cardinale Municipality

RFID technology monitors the number of trees in a forest area and can mark the trees fit for felling through tags and readers (MCU, Micro Controller Unit by Arduino). Round timber bears RFID marks, which are uploaded to and saved in the database. The SmartTree app provides access in the form of a Bluetooth connection. They load a means of transport with the marked pieces and take them to a sawmill. After a warehouse receives the wood, they mark pieces of the highest quality with a QR code and scan them again into the system (see Figure 4).



Figure 4. Wood monitoring through RFID, covering the full supply and production chain [90].

Ready-made products bear QR codes (two-dimensional barcodes) as well. The end customer can access their order and its status by scanning the QR code with a mobile phone app [91]. NFC (Near Field Communication) technology navigates across the forest using sensors or a mobile phone camera [91]. This results in real-time data, an inspection of the pieces and quality, transparent databases, analyses, management and decision-making support across the full production and logistics chain.

The SmartTree app (Figure 5) contains data on the marked pieces of round timber and allows for remote synchronised access using RFID technology. It contains three phases [91]:

1. Selection of the wood;
2. Cutting;
3. Server-database communication (Microsoft Azure Blockchain, IoT Hub interface).

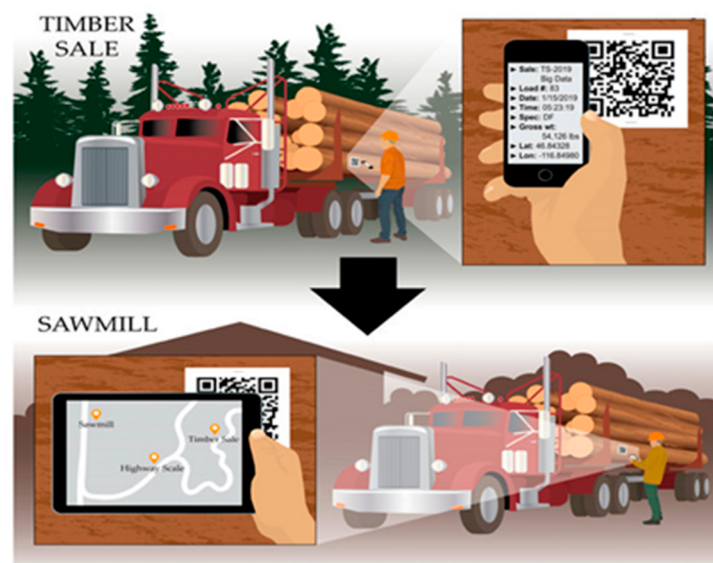


Figure 5. Illustration of the use of QR codes and the SmartTree mobile app [90,91].

The current processes of selecting, cutting, preparing, and producing the wood have changed, applying the new technologies.

The Cloud platform for IoT systems for wood-processing enterprises is called Tapio. Scanned data are transferred to a storage site, which one can access from multiple devices (tablets, smartphones, smartwatches, and others). This results in transparent processes, the sharing of information between departments, fast operational analyses, reduction in costs, and flexible solutions [92]. An employee being able to monitor the state of production equipment (the sawmill) is a relevant example. In the case of downtime, the sensor sends the employee a message about an error automatically. The Cloud saves a record of the failure, and other departments (maintenance) also receive an alert of that situation in real-time. The integration of the enterprise's teams and complex problem solutions are of benefit [92]. Although Cloud solutions are popular, In4Wood statistics highlight the fact that up to 85% of businesses do not use this technology. This research included a sample of forestry enterprises in Great Britain, Italy, Spain, and Germany; 64% of Italian sawmills are experimenting with Cloud solutions. As an "industrial country" behind the emergence of I4.0, Germany supports the implementation of the trend—32% of German sawmills use the Cloud, and 26% are experimenting with it [93].

5. The General Model of the Implementation of a Draft Solution

In the model, the implementation of IoT technology includes three in-house enterprise levels: the operative, tactical, and strategic levels, including entry of stakeholders from the external environment into the system. The operative level (the yellow part in Figure 6) includes data from an

input material warehouse, semifinished production, ready-made production, cameras on the premises, and primary production, which are measured and sent to an employee's (a warehouse worker's) tablet or mobile device through sensors. The tactical level (the purple part in Figure 6), which is middle management and is represented in enterprises less and less frequently, can be divided into two specific parts:

- **Logistical processes:** The operative level data are transferred through the warehouse worker's tablet and an internet connection to the enterprise's computer database. Primarily, the data enhance logistical processes for supplying, delivering input material, automatic programming and controlled drying of semifinished products, warehousing, searching through stock, and checking capacities (green colour in Figure 6).
- **Economic division:** Collects and analyses data, does paperwork, and prepares financial statements (pink colour in Figure 6).

The strategic level (blue part in Figure 6), or the enterprise management (Director, CEO), gains processed data (information) from the database through the Cloud storage site and the internet. They can browse the data using a tablet, a mobile phone, or a computer, and make decisions based on output documentation and charts. Realistic and verified data are supported by management and decision-making processes, including feedback (dashed line in Figure 6) at the enterprise management and the operative level (production and logistical processes, and customer services, can be made more efficient based on the data). The outside area (orange part in Figure 6), including customers and suppliers, who are two crucial external participants who can specify their requirements quickly and simply using mobile and web apps, makes the ordering process more efficient (supplier–enterprise, enterprise–customer).

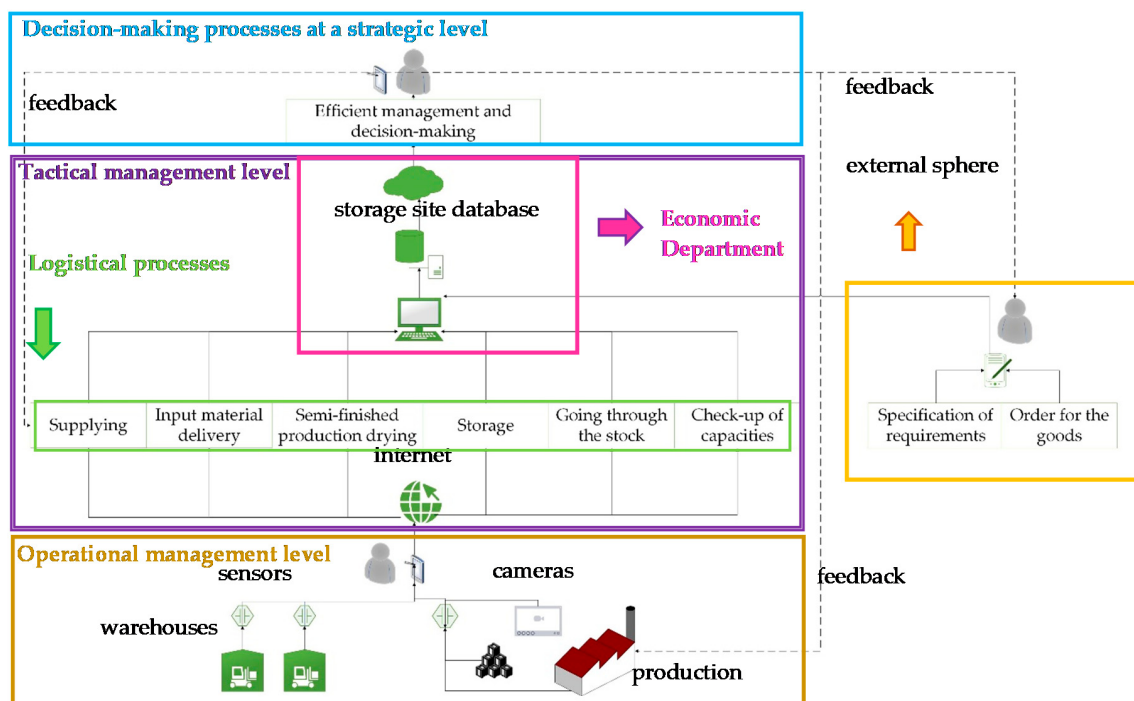


Figure 6. The general model of implementation of a draft solution.

A Procedure for Implementing Recommendations

After approval of the proposal, requirements are drawn up in order for draft recommendations to fulfil the management's preferences and acceptance criteria. Figure 7 shows a general model of implementing IoT technologies for supporting management, decision-making, and competitiveness

of Slovak enterprises. The next move is the choice of a supplier (depending on requirements) and appointment of a responsible employee who will run the new process and use the IoT technology. The subsequent step is the implementation of a specific proposal, arrangement of personnel training, and re-engineering of the present logistic processes.

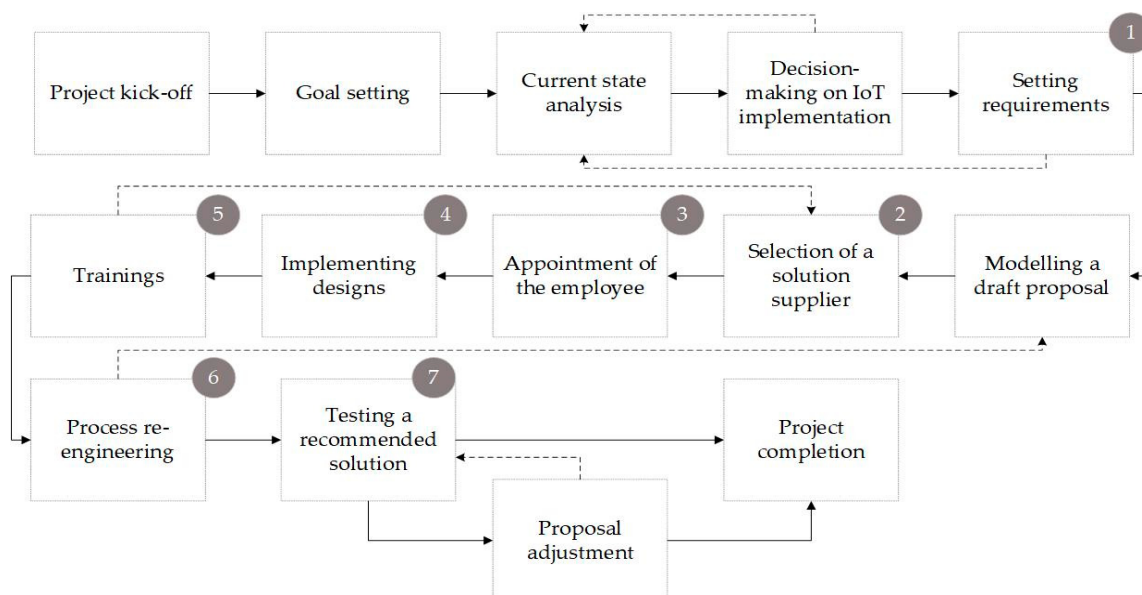


Figure 7. The procedure for implementing the set of recommendations, including potential problems.

Testing and verification of the recommended solution is an inevitable step to reveal mistakes, shortcomings, and duplications. The project is completed after adjusting the proposal to reach customer satisfaction. The green circles with numbers in Figure 6 represent the areas of potential problems which may occur in implementing IoT technology in the enterprise. The dashed line represents the feedback between individual activities; that is, the ones that depend on results of the preceding activities.

6. Discussion

The orientation analyses indicate the critical finding that the trend of environmental protection and the pressure to use the limited resources efficiently affects lumbering as well. Global powers such as the USA and Canada have a large number of sawmills which maintain low operational expenses and build customer relationships as a key success factor (through added value). Future predictions include the increase in wood production and consumption, affecting the growth of the price index globally. Weyerhaeuser and West Fraser Timber are the most significant global wood processors, who implement their software systems for simplifying logistical activities, procurement, installation, management, and decision-making support in-house, as well as externally (from the perspective of users). This results in sustainability and stable competitiveness in the market. The Slovak wood-processing industry helps reduce unemployment in the lower-qualification sector. However, the government's interference in the management of state forests causes various issues and lessens the positive effects of wood-processing. The sale of sawn wood will become the most significant among European Union countries by 2025.

The condition for maintaining and expanding lumbering, re-engineering processes, and customer care, and for introducing new technologies, is the stakeholders' right to support. To maintain competitiveness, enterprises must follow technological trends in the sector. Customers prefer personalised products, short delivery times, and quality for a reasonable price. The start of the 21st century saw the second wave of digitalisation. Wood-processing enterprises should thus start developing mobile apps to connect with their customers, using machine-to-machine (M2M), machine-to-people (M2P), and people-to-people (P2P) communication, and collecting and analysing

real-time data. Consultancy companies' data prove the assumption that investments into the IoT reduce costs, and the tendency towards investing available financial resources into this trend is growing; managers appreciate progress in storage, logistics, and production. The case study of the Italian sawmill highlights the benefit of the implementation of "tracking" radio frequency technology, RFID, in the supply and customer process (forest-end customer relations). The requirements for this include a Cloud platform, a mobile app, and a server. Efficient, simple processes and communication, as well as the integration of activities, are of notable benefit.

By implementing IoT technology in logistics processes, enterprises gain the following non-economic benefits:

- Enhanced competitiveness in the wood-processing industry, an increased number of visits to the enterprise, and operational expense savings.
- Implementing IoT technologies and new machines will efficiently increase work productivity, reduce the error rate and complexity, and remove the accumulation of stock and downtime.
- A strengthened image, real-time data, and a higher added value is mediated to customers, affecting their satisfaction, perception, and purchase behaviour directly.
- Management and decision-making support at all management levels. By following best practice procedures, the enterprise will gain valuable know-how and experience, which may lead to the analysed enterprise introducing a reference model for its competitors.
- New partnerships will be established by participating in logistical exhibitions and attracting the attention of the top enterprise in the sector in Slovakia (e.g., Rettenmeier tatra timber, s. r. o.).
- Reducing the customer's rejection or ignorance towards clients.
- Acquiring the necessary information for a future development strategy by assessing the logistical audit and satisfaction surveys regularly.
- Saving data in a single place through the Cloud, Cloud computing, servers and databases, at low cost, and with access possible from multiple devices (smartphone, tablet, pc, laptop, others).
- A change in employees' thinking will positively affect the enterprise culture and mood. It is essential to motivate and convince them that technologies are especially important nowadays, and that only enterprises which follow and implement trends will remain in the market.
- Gaining a competitive advantage: the enterprise can differentiate itself from its competitors and satisfy buyers' preferences and requirements by using unique elements of the IoT.
- Efficient internal (horizontal, vertical, or diagonal) and external communication.
- Optimised amount of inspection lines and service staff, less waste and fewer rejects, and information about OEE.
- Feedback, complex problem solutions, minimal costs of operational systems.

The predicted trends in Logistics 4.0 and the effect of noneconomic benefits will improve the logistical processes and competitiveness of wood-processing enterprises.

In addition to positive aspects, certain restrictions and technical requirements apply in implementing IoT technology in logistical processes in wood-processing enterprises. It is necessary to identify the main stakeholders (customers, suppliers) in the enterprise, as well as their requirements and preferences, and apply this knowledge to the modern production and distribution plans. Understanding the existing processes and their course is a crucial starting point. The barriers are:

- Limited financial resources for implementing the IoT.
- Insufficient employee qualification and motivation.
- Weak management support.
- Existing systems.
- An organisational structure.
- Politics, the culture.

IoT smartness lies in network scalability (the possibility to expand in the future in case of technology development). Further technical requirements concern:

- Security (personal data protection under the GDPR in 1.4.4.).
- Programming (development of prototypes and technical development models adjustable to customer requirements. These days, nonprofit educational academies, e.g., Khan Academy support programming).
- Data, data processing and saving: in the Cloud, Fog, and a reason for their virtualisation.
- Network management.
- Existing equipment and machines.
- Standardisation (associated with technologies).

Converged (unified) networks which eliminate barriers and technical requirements bring about a challenge, thereby ensuring quality infrastructure with low operational expenses for enterprises.

7. Conclusions

Slovak and global orientation analyses have proven the fact that the significance of the wood-processing industry is growing, with its success being dependent on the implementation of the elements of digitalisation in the operational sphere. Consultants' forecasts predict an increase in the use of smart devices in logistical and production processes. IoT trends will affect entrepreneurs predominantly until 2022, when the breakthrough of robotisation will come and continue until 2030. It is crucial to change the way of thinking and realise that technologies are not a threat and wasted expense, but rather an opportunity to enhance competitiveness, reduce costs, keep loyal customers, and attract new ones. The results of the case studies reviewed in this study point to the protection of domestic producers in north America's wood processing industry, which is achieving a higher price index globally [70]. The increasing trend of pulp consumption has also been reflected in Slovak consumers. The current situation requires the implementation of new technologies in the wood processing industry, as several Slovak companies have not achieved a sufficient level of competitiveness and maturity compared to companies such as West Fraser Timber or Weyerhaeuser. By using a general implementation model, companies can achieve related benefits, set an example for others, and develop not only their activities but also the entire region and state. After some time, the investment will bring about benefits on which global and domestic wood processors can build, achieving further success. The implementation of IoT technology in Logistics 4.0 and Wood 4.0 will protect limited resources and offer a new perspective on traditional operating activities. IoT technology mediates a change in logistical processes, preserving a positive nucleus on which the enterprise will build modern foundations of logistics in connection with Internet of Things technology. The effects of putting the model into practice will be assessed in future research.

Author Contributions: G.K. coordinated the research; D.Š. analysed the data; G.K. and D.Š. wrote the paper; All authors built the conceptual framework, and all authors contributed to the manuscript preparation. All authors have read and agreed to the published version of the manuscript.

Funding: This publication was realized with the support of the Operational Programme Integrated Infrastructure as part of the project "intelligent systems for UAV real-time operation and data processing", code ITMS2014+: 313011V422, and was cofinanced by the European Regional Development Fund.

Conflicts of Interest: The authors declare no conflict of interest.

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