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# IDENTIFYING THE FACTORS INHIBITING RESEARCH ON URBAN FREIGHT TRANSPORT IN DEVELOPING COUNTRIES: REVIEW OF STUDIES IN INDIA

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***Keywords:*** freight transport, urban freight, city logistics, developing economies, Indian cities
***Abstract:*** Most of the cities in developing countries are found to have non-uniform distribution of urban space, complex land use patterns, mixed traffic conditions, extensive use of non-motorized vehicles and lack of traffic discipline. In comparision to the developed countries, it is more complicated to manage urban freight transport in developing countries due to the lack of sufficient infrastructure, wide socio-economic gaps between urban and non-urban areas and haphazard peripheral developments. Therefore the methods and strategies used to manage urban freight transport in developed countries cannot be directly used for cities in developing countries. It is necessary to devise distinctive solutions to improve the efficieny of urban freight transport in these cities, which may otherwise, inhibit the economic growth of these cities as well as hamper the overall momentum of country's GDP growth gathered over decades. In recent years some studies focussing on urban freight transport are carried out in India, China and Brazil. This paper reviews urban freight studies carried out for Indian cities. India, world's second most populous country to China, has 39 cities with a million plus population. Most of its cities are facing problems like congestion and air quality degradation due to inefficient freight movement practices. Review of urban freight studies is carried out based on different parameters influencing efficiency of freight movement. Various challenges and limitations faced by the researchers and administrators are discussed. Based on the review results, suggestions and future scope for research in different aspects of urban freight are presented in the paper.

## 1 Introduction

Cities around the world rely on frequent and timely deliveries of goods and services to its residents, commercial and industrial units [1]. Practitioners and policy makers around the world have realized and acknowledged that goods transportation in cities have become a critical component in the urban transportation systems and therefore research in this area has also been intensified in the recent years. Unlike passenger transport, freight movement systems are very complex in nature, as there are several agents involved in the decision making at every stage [2]. Urban freight is studied quite extensively in the developed countries of Europe and the USA as compared to other parts of the world. In India too, urban freight studies is gradually gathering pace, yet it is at a very nascent stage. The studies carried out in developed countries cannot be directly implemented in India with respect to the research methods used in these studies because of a range of cultural, lifestyle and physical difference among them. Most of the Indian cities are characterized by high population densities, complex land use patterns, short trip length, and a high share of pedestrians and non-motorized vehicles (NMV) in the overall traffic. The transport and land-use patterns of cities in India are highly influenced by socio-economic and cultural complexities that makes it difficult to analyze their characteristics using the same indices as used for cities in highly motorized countries like the U.S or member nations of EU. In absence of critical analysis of research gap and eye opening research in this area, many researchers are avoiding to pursue research in the field of urban fright due to data scarcity, blind spots in problem statement, complexity of problem due to huge variety of goods and its handling methods, conflicting interest of various stakeholders involved, business secrets, tax policies and other such factors making urban freight transport (UFT) a less preferred area of research.

In the year 2013, India got categorized as a newly industrialized economy from a developing country [3]. A newly industrialized economy is a country whose economic development is between developing and highly developed economies. With 1.36 billion people, India's overall population is second highest in the world after China. India has 39 cities having population of more than a million. Of these cities, there are two having population in excess of 10 million - Mumbai and Delhi. There are 388 cities that have populations between 100 thousand and a million and also it has 2,483 cities with populations between 10 thousand and 100 thousand [4]. In general almost every city in India is facing problems due to its inefficient goods handling methods. In India, UFT is higly neglected in policy framing or city management [5]. Literature is available only for a few studies carried out in recent times, as some of the studies carried out by certain industry are only for internal use and hence not shared or published outside. The paper presents a review of urban freight studies carried out for different cities of India to analyze the factors inhibiting or restricting participation from research community as compared to passenger transport. The parameters used for conducting this review exercise have been derived from the various challenges and limitation faced by the researchers who have made some research progress in this area. It also intends to suggest practical recommendations that could facilitate urban freight studies in Indian cities for making UFT systems more sustainable.

### 1.1 Objectives of the study

Present scenario for overall environment for cities in India is not very encouraging. Due to very high of overall population, rapid urbanization, faster industrialization, and increased motorization of transport facilites; air and noise pollution is rapidly increasing in India [6]. In research studies as well as policy managment, road traffic and their impact on the liveability index of Indian cities have received growing attention in recent years, much of this attention is directed to passenger traffic [7]. Despite the fact that UFT is having a very significant impact on the overall liveability of the cities, it has received little attention. The aim of this study is to document research work carried out in this field to know the state of the art practices and improvement measures adopted across the country. In that sense, this study attempts to determine changes needed in policies and practices at develop efficient and sustainable UFT systems for the cities in India. The purpose of the study can be classified into three parts:

- To review the existing studies carried out by various researchers and transport planning professional in different cities of the country.
- To identify the gaps and voids in the systems that limits the role and contribution of research community in improving the current state of practice.
- To provide conclusive steps and practical recommendations for making the UFT systems in the country more sustainable.

The study is geographically restricted to India alone; however it is equally useful neighboring countries like Sri Lanka, Bangladesh and Pakistan where the traffic behaviour is similar in nature. Only documented literature in the form of research articles, conference papers and study reports by government and non-government organizations are considered for the review. Studies of urban freight movement only using roads as the mode of transport is considered in the study, other UFT modes like urban rail or trams and inland water transport are not considered.

### 1.2 Search Methodology

Secondary sources in the form articles in scientific journals, articles in press, book chapters, doctoral and masters dissertations and refereed proceedings are used in this review. To find relevant articles popular online databases from - Science Direct, Scopus, Web of Science and Google Scholar were used; keywords like urban freight, freight transport, city logistics, and goods movement were selected for search in title and abstract of the papers for filtering in first stage. Total of 1898 search results were obtained for the time period of 2000-2019 as a result of total studies carried out in the world. During the online search 24 reviews articles in peer-reviewed journal were found, specifically focusing on modelling techniques [8,9], bibliometric analysis [10], urban consolidation and distribution centers [11-13], survey methods [14], sustainability of urban freight [15,16], use of best practices and innovative technologies for freight handling [17-19] and logistics sprawl [20]. The search was further filtered for studies carried out in India. Only a handful of research publications were available on urban freight transportation in developing economies in reputed refereed journal. Further, articles presented at conferences, proceedings and archives of transportation background conferences wherein participation from Indian researchers is found; Transportation Research Board (TRB) Conference, World Conference on Transport Research (WCTR), Institute of City Logistics Conference, Conference of the Transport Research Group of India (CTRG), Urban Mobility India (UMI), Conferences and Eastern Asia Society for Transport Studies (EASTS) and other internationally reputed conferences were searched. Furthermore, studies carried under government projects by academic institutions or other independent consultant were searched from various government reports and other published reports. The review framework used in this paper is an adaption of the urban freight domain analysis suggested by Odgen and Crainic *et al.* [21,22]. Finally a total of 32 total articles were considered selected for reviewing the scenario of urban freight transport in India which is presented in this article.

## 2 Review process

An urban freight transport system is made up of numerous activities and stakeholders that results in formation of a complex subject to study, in order to understand these issues with simplicity a systematic review of each paper was carried out on the six aspects of urban freight transportation, which are discussed in this section.

### 2.1 Number of commodity/ services (C/S)

The overall impact of urban freight on city traffic can be estimated when all the freight trips attracted and produced are taken in to account. However, in cases where a single industry has very dominant presence in the city and its impact on the overall freight traffic is very high, studies restricted to only such industry can also prove to be very effective. However more such studies needs to carried out focusing on commodities of domestic need like industrial freight needs, FMCG goods, bakery and dairy products.

### 2.2 Size of study area

The geographical dimension or size of the area chosen for study varied largely in the current study. Some studies were carried out on very small study area like a single main market area (road stretch of 1.5 km); while some other studies included the entire city as well as the surrounding metropolitan areas in the study. Comparison of different cities for a particular parameter is also a form of study attempted by many researchers around the world. Study area is a very important factor determining the application of the study in policy making and hence included in the study.

### 2.3 Stakeholders

Stakeholders are people who take decisions for the goods movement. They are divided into five categories based on their attributes, behaviour and roles in the UFT process [23-25]. Details of these categories are as under:

- Administrator; which includes government bodies at the city, state and country level.
- Supplier; who produces and/or supplies various commodities or services to the study area.
- Carrier; who distributes the goods and services from suppliers to receivers outside or within the study area.
- Receiver; who receives various goods or service within the study area and uses or redistributes them.
- Residents; who are the end users of the various goods and services that are available in the urban area.

### 2.4 Study Objectives

Based on the stakeholder and study area chosen for the analysis, objectives may vary. As such the overall objective for any urban freight study is to reduce the social cost of city logistics [21]. However for the present review objectives are further divided into sub-categories like reducing cost, improving efficiency, environmental impact, safety of traffic operation, providing infrastructure, town and city's planning and knowledge enhancement which are classified based on stakeholders in Table 1.

*Table 1. Objectives of urban freight studies*

| Objective | Description | Key stakeholders |
|---|---|---|
| Reducing Cost | Minimization or reduction in transport operation costs | Supplier and Carrier |
| Improving efficiency | On time delivery, loading- unloading, parking of freight vehicles | Receiver and carrier |
| Environmental impact | Noise and air pollution caused due to congestion of urban roads | Administrator and residents |
| Safety of traffic operation | Reduction in the number of accidents and damage to property and life caused | Residents, Administrator |
| Providing infrastructure | Road construction and maintenance, provision for parking and transport hubs | Administrator and carrier |
| Town and city planning | Urban and logistics sprawl occurring in the city over years | Administrator |
| Knowledge enhancement | Some studies are carried to enhance knowledge which can be implemented at a later stage | Administrator and research community |

### 2.5 Survey Methodology

Depending upon the objective of the study and stakeholders considered in the study, the methodology adopted is bound to change. Also study area size is one of the very important factors for deciding the type surveys to be conducted. In cities of developed economies that have custom made models suiting to their freight flow pattern and data availability. But for a country like India where such studies are is yet in nascent stage, continuous and reliable data of freight flows are quite difficult to obtain. Different researchers have adopted different survey methods in their capacities and need for their research work [14]. Based on the several review papers studied the survey methods which are proved to efficient and effective in freight research elsewhere are listed belo:

- Establishment survey,
- Roadside interview survey,
- Commercial vehicles driver survey,
- Volume count survey,
- Supplier's survey,
- Commodity flows,
- Freight operator or service provider's survey,
- Parking inventory survey,
- Vehicle trip diaries,
- Secondary data sources.

Depending upon the scale of project more than one survey method may be needed for capturing the required information. Secondary data sources are also used for collecting information which is relevant to the study. Each of the above methods has their own advantages and limitation. These survey methods sometimes offer a trade-off between data accuracy and cost of data collection. Data collected during these methods may sometime overlap, which can be used as a cross-check of the data collected during the survey.

## 2.6 Applications of the study

As stated earlier from a researcher's point of view the primary purpose of any freight research study is to reduce the overall social cost of goods transportation and making urban freight more sustainable. Depending upon the key stakeholders involved in the study, the application of the work can be sometimes restricted to a particular section. At city level the application any freight study can be divided into four types, which can also be considered as four divisions defining the overall social cost of moving goods.

*Table 2 Review results of urban freight studies in India*

| Sr. No. | Author details | No of C/S | | Study area | | | Stakeholders | | | | | Objectives | | | | | | | Survey methodology | | | | | | | | | | Application | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Single commodity/service | Multiple commodity/service | Single street or market area | City or metropolitan area | Multiple cities comparison | Administrator | Supplier | Carrier | Receiver | Residents | Reducing Cost | Improving efficiency | Environmental impact | Safety of traffic operation | Providing infrastructure | Town and city planning | Knowledge enhancement | Establishment survey | Roadside interview survey | Drivers' survey | Volume count survey | Suppliers survey | Commodity flows | Freight operator's survey | Parking inventory survey | Vehicle trip diaries | Secondary data sources | Upgrading traffic policy | Suggestions for planning | Urban development | Urban and logistics sprawl |
| 1 | Kumar *et.al.* [24] | | ✓ | | | ✓ | ✓ | | | | ✓ | | | ✓ | | | | | | | | | | ✓ | | | | ✓ | | ✓ | | |
| 2 | Guttikunda & Kopakka [25] | | ✓ | | ✓ | | ✓ | | | | | | | ✓ | | | | | | | | ✓ | | | | | | | ✓ | | | |
| 3 | Baindur & Macário [26] | ✓ | | | ✓ | | | | ✓ | | ✓ | | ✓ | | | | | | | | | | ✓ | | ✓ | | | | | | | |
| 4 | Swamy & Baindur [27] | | ✓ | | ✓ | | | | | | | | | | | ✓ | | | | | | | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | |
| 5 | Divya Priya *et.al.* [28] | | ✓ | | ✓ | | | ✓ | | ✓ | | | | | | ✓ | | | ✓ | | | | | | | | | | | ✓ | | |
| 6 | Datta & Gupta [29] | | ✓ | | ✓ | | | | ✓ | | | | ✓ | | ✓ | | | | ✓ | | | | | | ✓ | | | ✓ | | ✓ | | |
| 7 | Bakshi *et.al.* [30] | | ✓ | | ✓ | | ✓ | | ✓ | | | ✓ | | ✓ | | | | | | | | | | | ✓ | | | ✓ | | ✓ | ✓ | |
| 8 | Sadhu *et al* [31] | | ✓ | | ✓ | | | | ✓ | | | ✓ | | ✓ | | | | | | | ✓ | | | | | | | ✓ | ✓ | | | |
| 9 | TCI – IIM [32] | | ✓ | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | ✓ | | | | | | ✓ | ✓ | | | ✓ | ✓ | | ✓ | |
| 10 | Gargava & Rajgopalan [33] | | ✓ | | | ✓ | | | | | ✓ | | | ✓ | | | | | | | | | | | ✓ | | | ✓ | ✓ | | | |
| 11 | Baveena [34] | | ✓ | | ✓ | | | | ✓ | | | | | ✓ | | | | | ✓ | | | | | | ✓ | | | ✓ | | ✓ | | |
| 12 | Goyal [7] | | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | | ✓ | | ✓ | | | ✓ | | | | | | | | | | ✓ | ✓ | ✓ | | |
| 13 | Kin *et al.* [16] | | ✓ | | | ✓ | | | | | | | | | | | | ✓ | | | | | | | | | | ✓ | | | ✓ | |
| 14 | Gupta [35] | | ✓ | | ✓ | | ✓ | | ✓ | | | | ✓ | ✓ | | | | | ✓ | | ✓ | | | | ✓ | | | | | ✓ | | |
| 15 | Gupta & Garima [36] | ✓ | | | ✓ | | | | ✓ | ✓ | | ✓ | | | ✓ | | | | ✓ | | | | | ✓ | | | | | | ✓ | | ✓ |
| 16 | Malik *et al.* [37] | | ✓ | | | ✓ | | | ✓ | | | | ✓ | | | ✓ | | | | | | | | | ✓ | ✓ | | | ✓ | | | |
| 17 | Pani *et al.* [38] | | ✓ | | | ✓ | | ✓ | | | | ✓ | | | | | | | ✓ | | | ✓ | | | | | | | | ✓ | | |
| 18 | Bhardwaj *et al.* [39] | | ✓ | | | ✓ | ✓ | | | | | | ✓ | ✓ | | | | ✓ | | | | | | | | | | ✓ | | ✓ | ✓ | |
| 19 | Sethia [40] | ✓ | | | ✓ | | | ✓ | | | | | ✓ | ✓ | | | | | | | | | | ✓ | ✓ | | | | ✓ | | | |
| 20 | Bakshi et al. [41] | | ✓ | | ✓ | | | | | | | | | ✓ | | | ✓ | ✓ | ✓ | | | | | | | | | | | ✓ | ✓ | |
| 21 | Erampalli *et al.* [42] | | ✓ | | ✓ | | | | | | | | ✓ | | | | | ✓ | | | ✓ | ✓ | | | | | ✓ | | ✓ | | | |
| 22 | Erampalli *et al.* [43] | | ✓ | | ✓ | | | | ✓ | | | | ✓ | | | | ✓ | | | | ✓ | | | | ✓ | | ✓ | | ✓ | | ✓ | |
| 23 | Gupta and Sinha [44] | ✓ | | | | | | ✓ | | | | | | | | | | | ✓ | | | | | ✓ | ✓ | | | | ✓ | | ✓ | |
| 24 | Pani & Sahu [45] | | ✓ | | ✓ | | | | ✓ | | | | ✓ | | | | | ✓ | ✓ | | | | | | ✓ | | | ✓ | | ✓ | | |
| 25 | Pani & Sahu [46] | | ✓ | | | ✓ | | ✓ | | | | | ✓ | | | | | ✓ | ✓ | | | | | | | | | | | ✓ | | |
| 26 | Pani & Sahu [47] | | ✓ | | | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | | | | ✓ | ✓ | | | | | | | | | | ✓ | | | |
| 27 | Pandya et al. [48] | | ✓ | | ✓ | | ✓ | | | | | | | | | | | ✓ | | | | ✓ | | | | | | | ✓ | | | |
| 28 | Dhonde & Patel [49] | ✓ | | | ✓ | | | ✓ | | | | | ✓ | | | | | | ✓ | | | | | | | | | | | ✓ | | |
| 29 | Dhonde & Patel [50] | ✓ | | | ✓ | | ✓ | | | | | | | ✓ | | | ✓ | | | | ✓ | | | | ✓ | | | ✓ | | | | ✓ |
| 30 | Dhonde & Patel [51] | | ✓ | | ✓ | | | ✓ | | ✓ | | | ✓ | | ✓ | | | ✓ | ✓ | | ✓ | | | | | | | | | ✓ | ✓ | |
| 31 | Dhonde & Patel [52] | | ✓ | | ✓ | | ✓ | | ✓ | | | | ✓ | ✓ | | | | | ✓ | | ✓ | ✓ | | | | | | | ✓ | ✓ | | |
| 32 | Middela et al. [53] | | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | | | ✓ | | | | ✓ | | | | | | | ✓ | | | ✓ | ✓ | | | |
| Total | | 6 | 26 | 0 | 21 | 10 | 10 | 10 | 14 | 6 | 4 | 5 | 16 | 13 | 4 | 3 | 3 | 12 | 14 | 0 | 7 | 5 | 1 | 6 | 15 | 2 | 2 | 13 | 15 | 16 | 9 | 2 |

- Upgrading traffic policy; the outcome of study results in or acts as a guideline for improving traffic policy in the study area. (example; Implementing traffic restriction for heavy commercial vehicles (HCVs) during peak hours)
- Suggesting planning principles; the study can develop analytical models which can guide planning decision of

city officials. (example; Infrastructure planning decisions like parking places and road planning)

- Adopting new technology; with use of geographic information systems (GIS) and global positioning system (GPS) technology and other intelligent transport systems (ITS) technologies, real time traffic and congestion status can be known which can improve efficiency of urban goods movement.
- Urban and logistics sprawl; temporal studies carried out for different times can help understanding the sprawl of city and logistics infrastructure like warehouse or consolidation centers, which in turn can help in long term city planning schemes.

Refining searches from various sources a total of 32 papers were selected for the review process. Each stage of the review process was carried out for each of these papers and review results have been summarized in table 2.

## 3 Review results and interpretations

Summary of research studies on urban freight transport carried out in India is presented in Table 2. The review is carried out based on six major parameters, number of commodities and/or services, study area and size, stakeholders, objectives of the study, and survey methodology and applications of the study. A total of 32 research works found from reliable and recommended sources are reviewed. Some other works found in local level publications and conferences which indicate only data collected for existing scenario of urban freight and any significant research outcomes are not observed, hence such works are omitted from the study to ensure that only quality works are considered to define the state of art for urban freight studies in India. The results of the review process and its interpretations are discussed in this section.

Number of services or commodities considered for the study considerably affects the research methods adopted. To assess the overall impact of UFT on the city's traffic it is necessary to consider all goods and services involved, however due to the limitations of availability time and resources it is very difficult to collect data for all the commodities and services of the city. However, in cities where some particular industry has very dominant presence and are generating majority of the urban freight trips, study of those particular commodity or service can prove to very useful. Six such studies have taken a specific commodity or service like municipal waste, timber etc, which are useful in planning of specific infrastructure sometimes not related to transportation, waste treatment plant or sawmills for instance [26-49]. Such studies can reduce the cost of data collection and yet give reasonably well results. More such studies focusing on freight movement of perishable goods and hazardous goods.

For the second parameter i.e. size of study area, it is observed that 21 out of 32 (2/3$^{rd}$) studies have considered entire city as the study area, while none of the studies have done micro-simulation or meso-simulation considering the freight impact of a single unit or a small area in the city, such studies have been very useful in solving urban freight issues in some cases [50-54]. A good number of studies have been conducted comparing different studies, which is a positive step towards designing nationwide policy of urban freight transport. Studies focussing on microscopic and mesoscopic level simulation of UFT are already conducted in cities of developed countries but are still not carried out for Indian cities.

Overview of stakeholders representation in the review suggest that administrators, shippers and carriers have greater contribution towards freight studies as compared to receivers and residents or end-consumers of the city. The role of administrator, directly or indirectly, comes into picture once the actual implementation of any research study is carried out in the city. There are some studies wherein role of carriers is independent of the administrator for example the case study of dabbawala's of Mumbai [27] and textile goods [52]. Suppliers are having more impact on the urban freight movement as compared to receivers. For majority of the commodities the responsibility of delivery of goods or services lies with suppliers. In case of UFT suppliers of goods and services are the wholesale and retail establishments in the city. The studies that are basically conducted to assess the environmental impacts of urban freight in the form of noise and air pollution have residents of the city as they key stakeholders.

Objectives of any UFT study needs to be very clear and well defined owing to its time and resource requirements. In the present study, seven major objectives of urban freight transport are considered in the review framework. These objectives are selected based on the framework from Odgen and Crainic [21,22] and as well as their relevance for the studies carried out in India; it is quite possible that in future some more objectives might be added in the list with development in technology and higher demand of frequent and timely deliveries. Most of the studies have shown that achieving efficiency in the system is the most important objective. Environmental impact of urban freight is the second most important objective; with India having some of the most polluted cities in the world it is not very surprising. Safety of traffic operation is a very major issue in India both for freight and passenger traffic leading to several accidents every day. Studies carried out in India are found very premature to give serious recommendations for infrastructure and town planning, lack of systematic and detailed land use data is one of the prime reasons behind it.

A review of survey methodologies adopted by various studies in India clearly indicate that establishment survey, freight transport operators' survey and secondary data are the most preferred methods. Establishment survey and freight operator's survey are the two tools which are more or less in control of the researcher and hence are the most reliable method for data collection. Secondary data sources are more useful obtain aggregate and periodic data; hence it is more useful for studies which are a sort of comparative analysis of two or more cities. Drivers' survey, commodity flow survey and traffic volume count are also used by some researchers, this methods of data collection are more suitable when the study are is small or study is restricted to particular commodity or service. Parking inventory and vehicle trip dairies data have limited scope in Indian scenario as the urban freight transport business is dominated by light commercial vehicles (LCVs) operating in a almost uncontrolled or unregulated manner [51]. Use of freight vehicles parking infrastructure is not done effectively and efficiently in many cities of the country and hence parking inventory data is not considered to be very reliable. Roadside interview method of data collection is not used in any of the study during the review; this survey tool has very limited application in urban freight studies across the world.

The last section of the review process accounts for the application of each study. Reducing the overall social cost of urban freight movement in the study is the ultimate goal of UFT studies in general, which is however categorized into four different applications as discussed in the sub-section on application of the study. Review results indicate that majority of the studies comes up with different suggestions that can improve the traffic policies (14 nos.) and freight transport planning (15 nos.) in Indian cities, and two studies focussing on urban or logistics sprawl. It is quite disappointing to find that none of the studies are considering technology improvement as a solution approach for city logistics related problems. Improving urban goods movement using latest technologies for vehicle routing and availability of real-time information about the road network are a common practice in developed economies nowadays, which is a distant future practice in India it seems. Private players like Amazon and Flipkart are using latest technologies for routing delivery trips and real time status, however such case studies aren't considered in the review due to lack of documented evidence.

## 4 Conclusions and suggestions

From the review it is also found that in India, majority of the research work on urban freight transport is carried out only in the last decade. However, the pace at which the interest of researchers is growing in this area is very encouraging. Based on the results obtained by different researchers in their respective efforts and some concluding comments made by them, authors have tried to present some concluding remarks and suggestion for future research in urban freight.

### *4.1 Conclusions of the study*

It is a very good sign for the cities of India that more and more researchers are developing interest in field of urban freight studies, but there is still a long way to go for solving various problems UFT systmes that cites in India are facing. From the present study it can be concluded that one of the major reasons limiting research effort in this direction in lack of systematic data collection related to urban freight in India. Unlike passenger transport, freight transport is not having a special cell or department looking after its growth and development in cities of India. Secondary data sources or urban freight transport are non-existent. In such a situation only premier institutes in the country like IITs and IIMs are able to make more efforts with their relatively larger impact. Most of the researches that have been carried out in the country are more or less only dependent on the primary data sources, which are very costly and time consuming. In absence of reliable secondary data sources, primary data collection consumes a lot of time, reducing the relevance of the research findings in some cases. Primary data collection gets very difficult with establishment becoming hesitant in sharing information owing to trade secret and tax hues. Collecting data from freight transport operators is relatively easy but for most of the major cities in India, urban freight transport is largely managed by LCVs, which are operated by individual vehicle owner like taxis and hence the movement of LCVs is literally haphazard and non-regulated. The brighter part of the study is that now researchers and policy makers have realized that urban freight is a very significant contributor to the overall traffic in terms of its impact on congestion and urban environment. Gradually, it has been widely accepted that considering freight vehicles as some proportion of the overall traffic is a very gross approximation and not advisable reference for taking crucial decision involving huge amount of resources and time.

### *4.2 Suggestions for future research*

There is an ample scope for improvements in the existing urban freight transport systems in the country and the insights gained from this review article would probably help many researchers and practioners to drive their future research endeavours in this direction. Based on the knowledge gained during reviewing the existing studies and the conclusions put forward, following are some suggestions by the authors for future research in urban freight transport in India

The review factors of the frameworks - number of commodities/ services, size of study area, stakeholder, objectives, methodology and application approach - are all interconnected and understanding these interconnections in a city's UFT system would be very useful in identifying research needs. From the review process some of the factors are found to be unexplored in Indian conditions, for instance microscopic simulation of urban freight generation or application of intelligent transport systems for UFT. Such gaps need to be filled in quickly for setting up a concrete foundation for future research. It is also observed during the study that majority of the studies are carried out in megacities only i.e. Delhi and Mumbai, however it is equally important to have efficient systems in other metros and medium size cities of the country. City specific or goods specific models needs to be developed as a medium term goal for each city supporting long term decision making process for investment in urban freight infrastructure of the cities. In long term, India should be able to come up with its own urban freight transport development manual guiding every aspect of urban freight transport like trip generation, infrastructure planning and freight transit oriented development in cities of the country, similar Institution of transportation engineers (ITE) guidelines and highway capacity manual (HCM). For achieving success in making urban freight movement more sustainable support and cooperation from all the stakeholders is inevitable. Sustainability and efficiency cannot come from one sided efforts by administrators alone. Stakeholders perception studies needs to be carried out before implementation of any policy.

During the review process, several research and review articles of the work carried out in USA, Europe and Japan were studies for understanding the progress of UFT research in those countries and find a comparison for studies carried out in developing countries. From some articles studied during the review process, some more innovative suggestions are given for new research avenues of urban freight which are probably unexplored in developing economies so far. The concept of circular economy which is largely restricted to manufacturing industry is now being implemented as a solution in urban freight for reducing the overall cost and environmental impact of good movement. This concept fundamentally proposes to reduce, reuse and recycle the waste of any process to improve sustainability (Genovese et. al., 2015; van Buren et.al., 2016). Most of the cities of developing countries are more congested and have mix land use patterns, LCV trips carrying small quantities for short distances often makes higher contribution to the overall freight trips. If electric freight vehicles are used for such trips, a lot of burden of noise and air pollution can be removed (Browne et. al., 2011; Van Duin et. al., 2013; Gruber et. al., 2014). Also shared private vehicle trips similar to models adopted for passenger transport like Uber can be adopted for urban freight transport. Sharing of freight trips would enhance productivity and reduced pollution at the same time (Patier et. al., 2014; Marcucci et. al., 2017). As mentioned earlier in the study, use of GIS and GPS technologies can be used for real time tracking of freight vehicles as well as geo-tagged parcels. These technologies are already in place for long distance or regional transport by various logistics providers, however its application in urban freight is very limited yet (Yang et.al., 2014). With more and more shopping going online and geo-tagging of vehicles, use of big data for user preferences can synchronize urban goods movement with several other infrastructures involved making goods flow smooth, easy and sustainable. The distribution and utilization of urban spaces in developing economies are entirely a different ball game as compared to the developed economies. Each and every aspect of urban freight needs to be studied from the perspective of developing countries to fill in various research gaps discussed in this paper. This review paper definitely help the researchers and policy maker to ponder in the research gap identified with the limitation of developing countries. Collaborative efforts from the research and urban administration fraternity should try to meet at one platform and endeavours to develop a think tank or special interest group which can work together for sustainable urban fright studies.

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# KINEMATICS OF POSITIONING DEVICE FOR MATERIAL HANDLING IN MANUFACTURING

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***Keywords:*** kinematics, positioning device, matrix methods
***Abstract:*** Different types of robots are used in many areas of industry. Industrial manipulators are used to ensure productivity and flexibility in automated production lines. Most of them is used for tasks that automatically repeat the same operation in a familiar environment. The key element in the development and analysis of industrial robots is their kinematic analysis. The article deals with the kinematic analysis of this positioning equipment. Individual relations of kinematic quantities are plotted graphically. Matrix methods were used for the analysis.

## 1 Introduction

People have thousands of sensations, movement and intelligence that coordinates them and adapts them to their current environment. Industrial robot has only a few sensors and the ability to perform certain movements, but without a human assistance it lacks the intelligence to adapt to its new task. In manufacturing, individual robots are programmed to perform one group of tasks and need to be reprogrammed for another group of tasks. The main difference between a human and a robot is flexible decision making. Up until now, robotics technology has not made a large impact in the world of logistics. This is change as advanced robots enter our warehouses, sorting centres, and even help with final delivery. Logistics workers has benefit from collaborating with robots, while customers are seeing faster service and higher quality. The main reason for the lack of logistics robots is techno logical. Until recently, robots have been stationary, blind, and relatively unintelligent. They perform the same movements over and over again thousands of times a day with a high degree of accuracy and precision. For many simple manufacturing processes, such as welding or transferring parts, these skills are all that are needed. The world of logistics, however, is much more complex than manufacturing and requires a robot with more ability.

The automated assembly line connects industrial robotic manipulators and various robotic equipment for material transporting, positioning and moving. The main elements of robots are common to many industrial systems. Individual handling equipment is designed to pick up the material and precisely transport it from one position to another. These devices handle the material in cooperation with a human. This makes it easy for people to manipulate even heavy objects [1-7].

The handling or positioning device can be considered as an open kinematic chain. The basic precondition for the operability of the device is a reliable calculation. The actual construction of the device depends on the calculation of the relevant mechanical quantities, which determine the dimensioning of individual components or nodes of the device [8-15]. The actual calculation is performed after a simplification of the investigated device on a mechanical model, which includes all main parameters of the actual device affecting the behaviour of the device according to its design. For the purpose of a mechanical model, all devices can be in general understood as a bound system of bodies [16-25].

The movement of the mobile robot in the work environment is shown in Figure 1 [3]. Sensors monitor the working environment of the robot with control system and navigating his movement in the production environment. The mobile robot enables communication between the operator and the robots. Depending on the mobile platform, different degrees of automation are added to the control system.

Industrial production currently requires new logistics concepts in the production premises, which are intelligent, versatile, networked, modular and also mobile. Mobile devices should have the ability to work between people and the production line. As well as people deployed in the production of mobile robots, they can monitor the working cycles of the machines, move freely around them and connect the individual production sites and thus create new, highly flexible production units. For example, the mobile and intelligent KMR iiwa is also shown in Figure 1

[3]. An example of a mobile robot model in the workflow environment of a production process made in the MSC Adams program is shown in Figure 2 [[4-8,21]. Each robot contains a gripping device.


*Figure 1 Mobile robot KUKA KMR iiwa [3]*

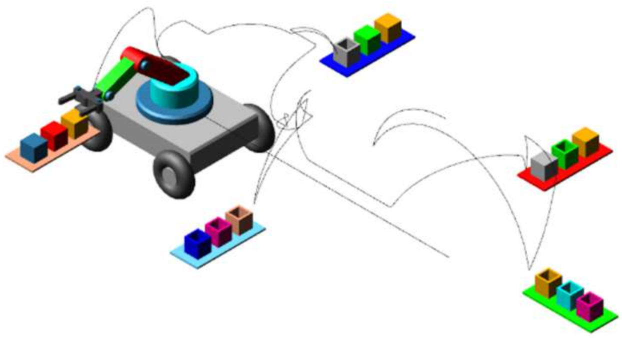

*Figure 2 Model of mobile robot in MSC Adams View and trajectory of end-effector [4]*

The end effector is a separate part of the robot, which is used to hold the manipulation object - the gripper. In industrial robots, a technological head such as a welding torch, a painting nozzle and the like is often used as an effector. In this paper, we further focus on the gripper representing a mechanism with three degrees of freedom of movement. The kinematic analysis of individual members is given in the following sections.

## 2 Kinematic analysis of bound systems of bodies

The main principle of analytical kinematic analysis of bound systems is in determination of the relations of geometric quantities describing the position of significant points of the driven members on the position of the driving members [5-10]. Based on the position, the speed and the acceleration of the individual members can be determined.

The kinematic and dynamic analysis of a system of bodies uses software, which are often based on the matrix methods. Individual physical vector quantities are entered in matrix notation. In matrix method the coordinates are transformed. Orthogonal transformation is used for this transformation [4,20].

It is necessary to properly select the coordinate systems of the individual members of the system to simplify the calculation. In the case of a revolute kinematic pair, it is advantageous to select one coordinate axis as the axis of rotation. The remaining axes are selected to suit the shape of the body or the location of the next kinematic pair. With a prismatic kinematic pair, we place one axis in the direction of the linear motion [10-16]. Transformation matrices expressing the respective rotations around the individual axes are used to define the spherical motion. Transformation matrices of relative motions and vectors of the relative positions of the origins of the coordinate systems can be compiled for the selected coordinate systems. This gives the necessary relationships for the numerical calculation of the position vector for the given relative positions of the members of the mechanism [20].

The disadvantage of the derived matrix relations for the position, velocity and acceleration of the kinematic chain is the fact that it is necessary to make products of matrices and vectors but also a number of sums. This makes the expressions rather unclear and the calculations are time consuming. It is convenient to use so-called homogeneous coordinates and work with extended matrices and vectors to eliminate this disadvantage. Matrix relationships for the position, velocity and acceleration of the mechanism can be used for analysis but also for some tasks of mechanism synthesis. The matrix method enables the kinematic analysis of any complex planar and spatial mechanism [4,20].

The movement of a member of the bound system or one of its points is achieved by several simultaneous movements of the system. The movement of the *n*-th member of the system can be expressed by means of a position vector or the parametric equation (1) of the trajectory of the point M

$$r_{1M} = T_{12} \cdot T_{23} \ldots T_{n-1,n} r_{n,\mathrm{M}} \tag{1}$$

where $T_{1n}$ is the transformation matrix of the motion n:1 and the following expression (2) applies

$$T_{1n} = \prod_{i=1}^{n-1} T_{i,i+1} \,. \tag{2}$$

The velocity of the point M can be expressed by the relation (3), (4)

$$v_{1M} = T_{14} V_{14} r_{4M}, \tag{3}$$

$$\text{where } V_{14} = V_{12} + V_{23} + V_{34} = T_{34}^{-1} T_{23}^{-1} V_{12}^{(2)} T_{23} T_{34} + T_{34}^{-1} V_{23}^{(3)} T_{34} + V_{34}^{(4)} \tag{4}$$

Acceleration of any point M (5) of member 4

$$a_{1M} = T_{14}A_{14}r_{4M} \tag{5}$$

where $A_{14}$ (6) is the complete acceleration of member 4 relative to member 1 and is expressed by the relation

$$A_{14} = a_{14} + V_{14}^2 \tag{6}$$

The partial acceleration matrix $a_{14}$ is expressed (7) by the Resal acceleration.

$$a_{14} = \dot{V}_{14} = A_{12} + A_{23} + A_{34} + A_R \tag{7}$$

where $A_R$ (8) is Resal acceleration and is expressed by the relation.

$$A_R = (V_{12}V_{23} - V_{23}V_{12}) + (V_{12}V_{34} - V_{34}V_{12}) + (V_{23}V_{34} - V_{34}V_{23}) \tag{8}$$

## 3 Movement of members of the positioning device

Diagram of the positioning device in the Figure 3, represents an open kinematic chain with three degrees of freedom of movement. For the positioning device, the equations of motion of the point M of the member 4 with respect to the other members were derived. The configuration in Figure 3 corresponds to the position of the device in time $t = 0\,s$.

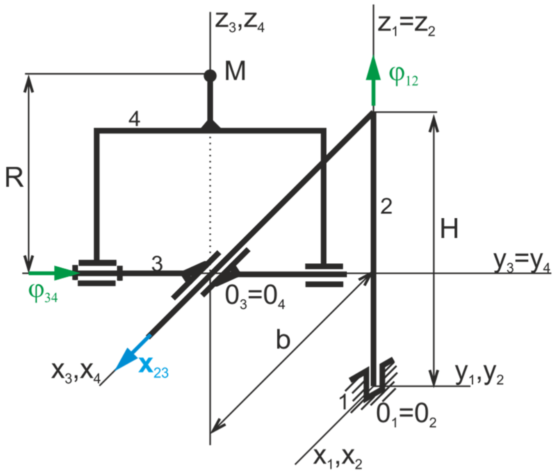


*Figure 3 Positioning device in the initial position in time t = 0 s*

Local coordinate systems are introduced in individual members of the system, Figure 3. During the relative motion of member 2 to member 1, the z-axis remains identical in each position ($z_1 = z_2$). The coordinate axes $x_2, y_2$ are identical to the axes $x_1, y_1$ only in the initial position for time $t = 0\,s$. The member 2 performs a rotational movement with respect to the base 1 and the rotation angle $\varphi_{12}$ of the member 2 relative to base 1 is function of time. The origin of the coordinate system of member 3 is shifted by the value H in the direction of the z-axis and by a value b in the direction of the axis $x_3$ of member 2. Member 3 performs a sliding movement with respect to member 2, where $x_{23} = x_{23}(t)$. The member 4 rotates about the axis $y_3 = y_4$ of the member 3 by an angle $\varphi_{34} = \varphi_{34}(t)$. The position of the end point M of the member 4 is at a distance R.

The matrix equation of the trajectory of point M of the positioning device is (9)

$$r_{1M} = T_{12} \cdot T_{23} \cdot T_{34} r_{4M} \tag{9}$$

The respective transformation matrices (10), (11), (12) of basic movements of the positioning device are

$$T_{12} = T_{\varphi_z}(\varphi_{12}) = \begin{bmatrix} c\varphi_{12} & -s\varphi_{12} & 0 & 0 \\ s\varphi_{12} & c\varphi_{12} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{10}$$

$$T_{23} = T_{p_x}(x_{23}) = \begin{bmatrix} 1 & 0 & 0 & (b + x_{23}) \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & H \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{11}$$

$$T_{34} = T_{\varphi_y}(\varphi_{34}) = \begin{bmatrix} c\varphi_{34} & 0 & s\varphi_{34} & 0 \\ 0 & 1 & 0 & 0 \\ -s\varphi_{34} & 0 & c\varphi_{34} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{12}$$

The transformation matrix (13) of member 4 with respect to member 1 is

$$T_{14} = T_{12} \cdot T_{23} \cdot T_{34} = \begin{bmatrix} c\varphi_{12}c\varphi_{34} & -s\varphi_{12} & c\varphi_{12}s\varphi_{34} & (b + x_{23})c\varphi_{12} \\ s\varphi_{12}c\varphi_{34} & c\varphi_{12} & s\varphi_{12}s\varphi_{34} & (b + x_{23})s\varphi_{12} \\ -s\varphi_{34} & 0 & c\phi_{34} & H \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{13}$$

substituting equations (3) to (5) into (1) and (2) we get the equation of the trajectory of point M of member 4 in the coordinate system of base 1 using the basic matrices (14):

$$r_{1M} = T_{12}.T_{23}.T_{34}.r_{4M} \tag{14}$$

The extended position vector (15) of the point M in the space of the member 4 is

$$r_{4M} = [0 \quad 0 \quad R \quad 1]^T \tag{15}$$

Position vector (16) of point M with respect to the coordinate system $O_1$, $x_1$, $y_1$, $z_1$.

$$r_{1M} = T_{14}.r_{4M} = \begin{bmatrix} c\varphi_{12}(b + x_{23}) + Rc\varphi_{12}s\varphi_{34} \\ s\varphi_{12}(b + x_{23}) + Rs\varphi_{12}s\varphi_{34} \\ H + Rc\varphi_{34} \\ 1 \end{bmatrix} \quad (16)$$

Three variants of the input parameters were selected to calculate the movement of the positioning device. They are listed in Table 1.

*Table 1 Input parameters*

| | $\dot{\varphi}_{12}$ (rad/s) | $\dot{\varphi}_{34}$ (rad/s) | $\dot{x}_{23}$ (m/s) |
|---|---|---|---|
| P1 | 1 | 1 | 1 |
| P2 | 0.5 | 0.5 | 1 |
| P3 | 0.35 | 0.35 | 1 |

Figure 4 shows the trajectory of the point M for respective input data according to Table 1. The relations of the individual components of the position vector are for variants P1 to P3 in Figure 4 to Figure 6.

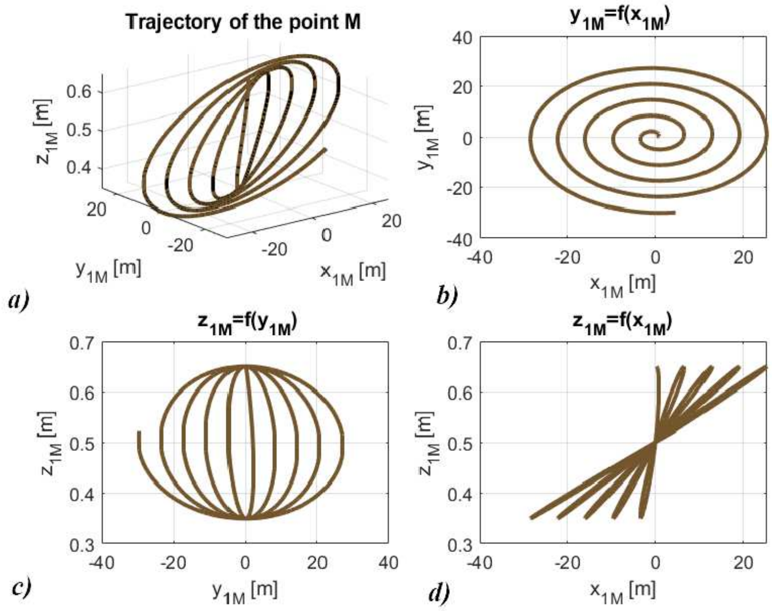


*Figure 4 Trajectory of the movement of the point M for the input data P1: a) input data P1, b) y = y (x), c) z = z (y), d) z = z (x)*

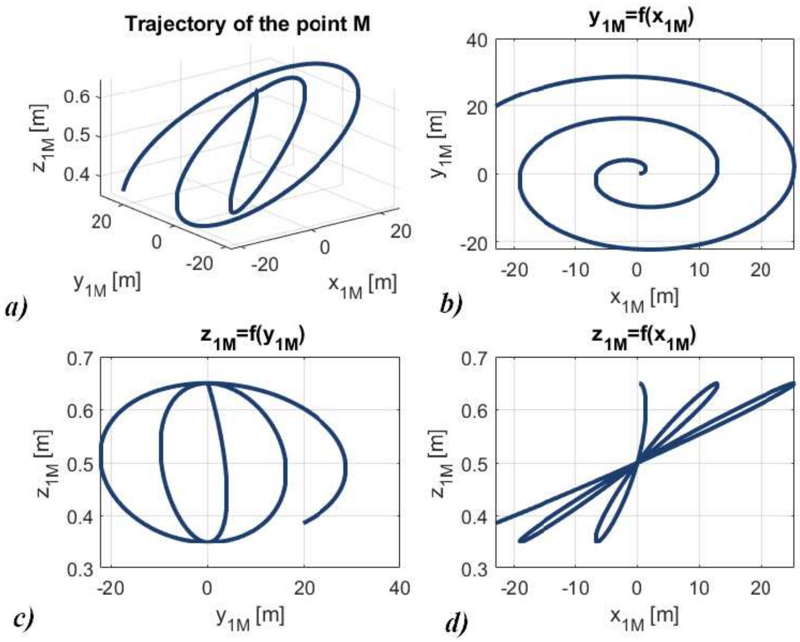


*Figure 5 Trajectory of the movement of the point M for the input data P2: a) input data P2, b) y = y (x), c) z = z (y), d) z = z (x)*

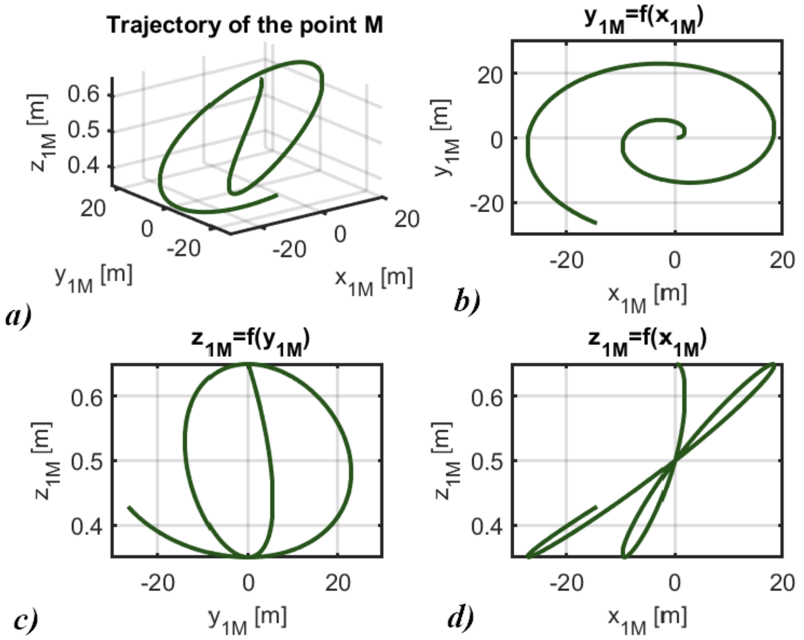


*Figure 6 Trajectory of the point M for the input data P3: a) input data P3, a) y = y (x), b) z = z (y), c) z = z (x)*

Figure 7 shows the time graph of the position vector of the point M for respective input parameters.

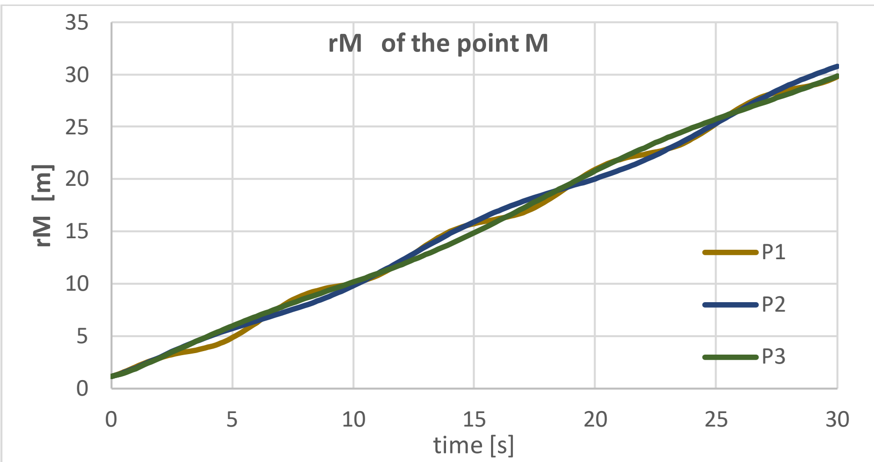


*Figure 7 Time graph of the position vector*

The mathematical expression of the components of the velocity vector (17) is

$$v_{1M} = T_{14}V_{14}r_{4M} = \begin{bmatrix} \left(R\dot{\varphi}_{34}c\varphi_{34} + \dot{x}_{23}\right)c\varphi_{12} - \left(b + x_{23} + Rs\varphi_{34}\right)\dot{\varphi}_{12}s\varphi_{12} \\ \left(R\dot{\varphi}_{34}c\varphi_{34} + \dot{x}_{23}\right)s\varphi_{12} + \left(b + x_{23} + Rs\varphi_{34}\right)\dot{\varphi}_{12}c\varphi_{12} \\ -R\dot{\varphi}_{34}s\varphi_{34} \\ 0 \end{bmatrix} \tag{17}$$

The relation of the velocity vector of the point M with respect to the basic coordinate system $O_1$, $x_1$,$y_1$, $z_1$ for the individual input parameters is shown in Figure 8.

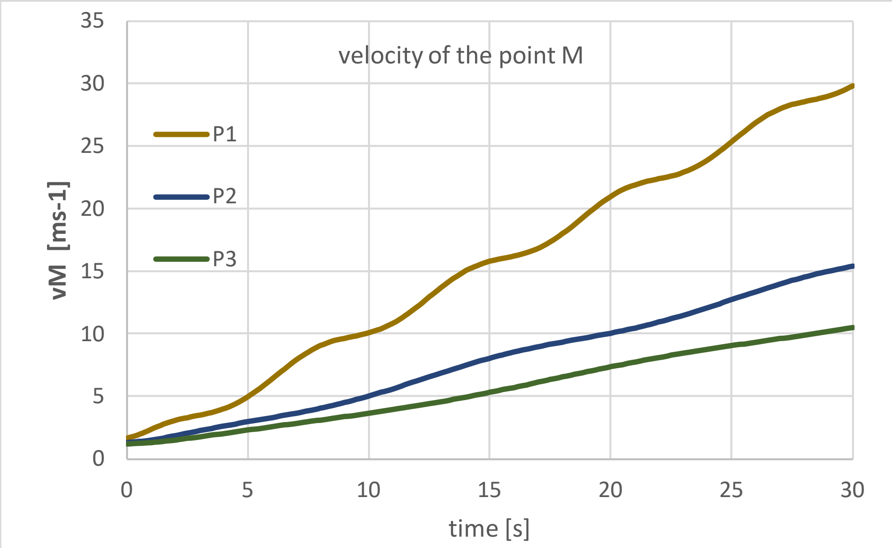


*Figure 8 Time graph of the velocity vector*

The acceleration components of point M with respect to base 1 are (18), (19), (20).

$$a_{1Mx} = \left(R\ddot{\varphi}_{34}c\varphi_{34} + \ddot{x}_{23} - R\dot{\varphi}_{34}^2 s\varphi_{34}\right)c\varphi_{12} - \left(b + x_{23} + Rs\varphi_{34}\right)\ddot{\varphi}_{12}s\varphi_{12} - \\ -\left(b + x_{23} + Rs\varphi_{34}\right)\dot{\varphi}_{12}^2 c\varphi_{12} - 2\dot{\varphi}_{12}\left(R\dot{\varphi}_{34}c\varphi_{34} + \dot{x}_{23}\right)s\varphi_{12} \tag{18}$$

$$a_{1My} = \left(R\ddot{\varphi}_{34}c\varphi_{34} + \ddot{x}_{23} - R\dot{\varphi}_{34}^2 s\varphi_{34}\right)s\varphi_{12} + \left(b + x_{23} + Rs\varphi_{34}\right)\ddot{\varphi}_{12}c\varphi_{12} - \\ -\left(b + x_{23} + Rs\varphi_{34}\right)\dot{\varphi}_{12}^2 s\varphi_{12} + 2\dot{\varphi}_{12}\left(R\dot{\varphi}_{34}c\varphi_{34} + \dot{x}_{23}\right)c\varphi_{12} \tag{19}$$

$$a_{1Mz} = -R\ddot{\varphi}_{34}s\varphi_{34} - R\dot{\varphi}_{34}^2 c\varphi_{34} \tag{20}$$

The relation of the acceleration vector of the point M with respect to the basic coordinate system $O_1$, $x_1$,$y_1$, $z_1$ for individual input parameters is shown in Figure 9.

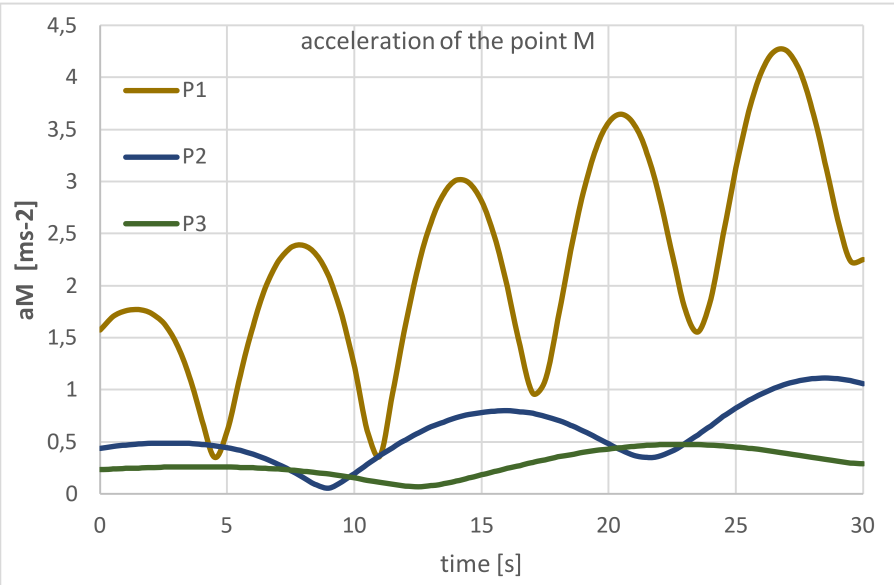


*Figure 9 Time graph of the acceleration vector*

## 4 Conclusions

The movement of individual members of the positioning device was addressed. Software was used to compile and evaluate matrices describing the movement of device members. The article presents the procedure for solving the problem of kinematic analysis of mechanisms by matrix notation, the principle of which are used by individual software for kinematic and dynamic analysis. The results are in the form of a time graph of the individual parameters determining the movement. At the same time, the trajectory of the movement of the positioning device endpoint is plotted depending on the individual coordinates. The contribution of the paper is mainly in the didactic area as a suitable tool for solving the problems of kinematics of the motion of a mechanism.

The results of the solution position, speed and acceleration of the robot endpoint for the selected member speeds are shown graphically. From the calculated kinematic quantities, we see that the movement of the end point of the robot is uniform at lower speeds. At higher speeds, the course of the dependence of the position vector on time acquires a sinusoidal character, which can be seen in the graphs.

**Acknowledgement**

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# THE USE OF PROGRESSIVE GRAVITATIONAL METHODS IN THE LOGISTICS OF RAIL PASSENGER TRANSPORT

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***Keywords:*** gravitational methods, passenger transport, railway, timetable, optimal traffic service
***Abstract:*** The main strategic goal of EU transport policy is to support public passenger transport and railway transport as a key transport mode. It is also very important to develop and improve logistic processes in passenger transport. To meet these goals it is necessary to use professional and scientific methods, for example gravitational methods. These methods can be included among progressive empirical methods and models that are used to generalize specific results and offer a general solution to the problem, from practical knowledge to theoretical formulation. These methods are utilised in the natural sciences but their using in transport processes is very important too. One of the best known empirical methods are Nyvig´s and Lill´s gravitational methods. They are especially used in transport planning and organizing, determining of the traffic potential, optimization and rationalization of timetables and traffic service. In the contribution the authors deals with using of the current and new progressive gravitational methods in the context of rail passenger transport logistics. The first chapter comprises narrow connection of the logistics and rail passenger transport including the explanation of their function in rail passenger transport. The next chapter contains an analysis the current research of raised issues. The most important scientific part conssists of theoretical concept of the gravitational methods in railway passenger transport and its various modifications. Theoretical principles of the new progressive Lill´s gravitational model form including its practical application at the chosen railway passenger transport routes are explained and analyzed in the fourth and the fifth chapter.

## 1 Introduction

Gravitational models and methods are generally used in activities that show certain facts and produce specific results. They are based on conceptual thinking, system approach and exact features. They are engaged in gathering materials, constantly observing and investigating different processes. Subsequently, the measurement phase consists of a phase of counting and scaling, and finally, the experimental phase in which the process under investigationis carried out in its basic conditions and at the same time is isolated from other unimportant circumstances. Within the experiment, the process is changed based on the measurements, surveyed conditions and other selected criteria. Gravitational methods belong to the empirical methods. These methods should help to generalize specific results and offer a general solution to the problem, from practical knowledge to theoretical formulation. The main instruments used in the transition to general theoretical knowledge is induction.

The widely applied application of the methods is especially in the field of transport processes and traffic planning. Basic principles of gravitational methods and models are mentioned in publication [1]. An important practical application is mostly in railway passenger transport. The methods can be used in order to calculate optimal number of journeys, return trips, number of trains and so on. Current gravitational methods and the new proposed methods can improve and optimize traffic service in railway passenger transport. Finally, it should help to make railway passenger transport more attractive and effective and to increse the quality of logistic processes.

## 2 Logistics and its functions in railway transport

The relationship between transport and logistics is very narrow and. Transport ensures the physical relocation of the product from the place of production to the point of consumption and logistics try to find optimal solution of the transport process. Transport is an important factor in time benefit, it is the carrier of reliability and speed of product relocation. It is one of the most substantial elements in the logistic system. It has irrecoverable and unsubstitutable place in the logistical chain from material supplier to customer.

When choosing the optimum kind of transport and the transport mode, it is very important to take into account, in particular, the characteristics and type of the transported good, the weight, the volume, the packing methods, the legislative rules and other conditions. In this selection, account must be taken of the characteristics of the various modes of transport:

- ability to maximize transport safety, including the elimination of shocks and possible damage to the goods,
- ability to minimize the transport costs,
- the ability to provide traffic to any destination,
- ability to transport a certain number of materials and goods,
- ability to provide the optimal degree of time security and reliability,
- ability to provide the maximum degree of comfort.

Rail transport do not provide such high level of availability, manoeuvrability and flexibility as road transport, but in logistics, however its function is very important. It can provide transport in much larger quantities, in the case of freight transport offers the possibility to transport also heavy loads, shipments with specific properties, etc. Thus, it can offer a more favourable transport price per unit of consignment (e.g., ton). In the field of passenger rail transport, logistics deals with planning, organization, management and control of all activities between operators entering the transport process. The main goal is to create optimal conditions for ensuring safe, reliable, sufficiently fast and convenient passenger transport at the optimum price level. Very important is also synergy effect and cooperation with other types of transport. The basic strategic objective is to ensure the maximum quality, speed and comfort of the transport in regions and their economic development. To achieve this goal, the most appropriate solution is the introduction of an integrated transport system, integrating transport and tariff conditions, increasing the coordination of transport modes and co-operation between individual carriers. The more integrated the transport system is better for the traveling public and the logistics of public passenger transport at a higher level. The main tasks of logistics in passenger rail transport are [2]:

- review of passenger transport flows at certain times in transport routes using marketing methods or other survey methods,
- optimization and control of the transport streams,
- improving of the majority transport process factors,
- improving of the relationship with customers,
- ensuring quality services and optimal travel culture – cleanliness and comfort of the means of transport, seating, technical condition of the vehicle,
- ensuring optimal costs,
- solving the complex logistics chain – road from house to house.

## 3 Current research in the field of gravitational methods and models

Logistic problems in rail passenger transport and especially optimization of rail passenger transport, using various methods and models of transport planning are addressed by a large number of transport experts and scientists. Our target is focused to research a relationship between transport planning alternatively traffic service and logistics in rail passenger transport in the frame of sustainable transport system.

Using of the optimization methods Monte carlo is described in the article [3]. This method was used to optimize the fleet capacity. In [4,5] the authors focus on the quality of the service provided. As the interval between connections on individual lines is one of the qualitative indicators, such an assessment can be used. It is possible to connect innovative ideas in the field of transport using ontology. Optimisation of train traffic logistics often depends on various types of data storage and data representation. Many public transport providers are now connected to open data sets and various information systems beyond the field of rail traffic. Such domain interconnection needs smart ways of data storage for further processing and analysis. Solution described in [6] proposes using ontology as a modeling tool within the information system architecture proposal. This approach could be an inspiration in a further storage and analysis of passenger traffic data.

For example the Czech authors Jánoš and Kříž deal with issue of the gravitational methods and models in publications [7] and [8] where are explained basic principles and theoretical basis of the Lill´s gravitational models and subsequently its practical application in transport planning and determination of development forecast in Ústí nad labem region. Author Turner in publication [9] applies the principles of gravitational methods to air transport using several modifications and extended forms of the Lill´s gravitational model where is analyzed impact of aggregated and non-aggregated models to the issues. Within the proposal of the extended model deals with proposal of the new formula for model determination where are proposed several variables, the values of which are determined by expert estimation.

## 4 Current theoretical concept of the gravitational methods and models

This method is often used to calculate the direction of traffic flows in a four-stage traffic model. It is an important synthetic method that uses knowledge from another field of science (especially physics), taking into account Newton's law of gravitation, whose definition is as follows: “Consider two bodies of masses $m_1$ and $m_2$. The distance between the centers of masses is r. According to the law of gravitation, the gravitational force of attraction F (1) with which the two masses $m_1$ and $m_2$ separated by a distance r attract each other is given by”:

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$$F = G * \frac{m_1 * m_2}{r^2} \quad (1)$$

After the application of the law of gravitation to the direction of transport flows, the formula (2) is follow:

$$D_{ij} = k_{ij} * \frac{DZ_i * DC_j}{w_{ij}^{\alpha}} \quad (2)$$

where:
$D_{ij}$ - the number of journeys between areas i and j [piece],
$k_{ij}$ - gravitational constant [-],
$DZ_i$ - transport attractiveness of the area i,
$DC_j$ - transport attractiveness of the area j,
$w_{ij}$ - transport distance between areas i and j [km],
α - empirical value approaching 2 [-].

It is possible to take into account the more attractive the two monitoregravityd areas (i, j) and the lower the transport distance between them, thus higher traffic flows can be expected and higher number of journeys between them. The mentioned problem is expressed graphically in fig. 1. One of the most important gravitational methods is Lill´s gravitational model. The Lill's gravitational model and its various modifications are described in other subchapters [10].

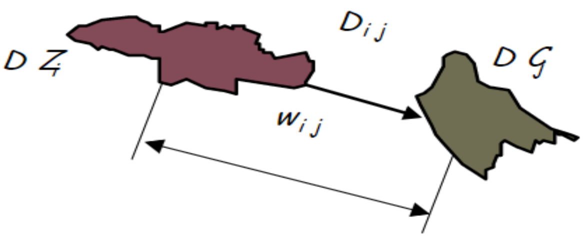


*Figure 1.Basic principles of gravitational methods* [11]

## 4.1 *Basic form of the Lill´s gravitational model*

Lill's gravitational model represents the most important source of motivation and inspiration for authors in scientific research. This model was created on the basis of the research activities of the Austrian railway engineer and transport modeling expert Eduard Lill, who already in 1891 presented the main principles and laws of travel in Vienna. Given the growing importance of his ideas, it was considered appropriate to apply the principles of his travel law to rail transport. Lill considered his observations to be a natural law analogous to Newton's law of gravitation in physics, but he had a fundamentally different theoretical approach. The original formulation was based on the hypothesis that there is a certain relationship between traffic flows between certain areas (settlements), the attractiveness of these areas and their distance. These traffic flows or the number of trips (passengers) within a given area is also called the "travel value" and can be expressed as follows (3) [10]:

$$y = \frac{M}{x} \quad (3)$$

where:
y – travel value, number of trips [piece],
M – attractiveness of monitored areas due to their size, economic level and other characteristics,
x – transport distance [km].

The above formulation of the relationship expresses the direct proportionality of the number of people with the attractiveness of the area and the indirect proportionality with the transport distance between them. This means that the number of passengers between two areas (settlements) decreases with increasing distance according to the hyperbolic curve 1/x. The hypothesis from which this formulation arose was subsequently confirmed and on the basis of further Lill's research new relationships were formed expressing the given issue [10].

## 4.2 *Current modified forms of the Lill´s gravitational model*

For example, research based on determining the number of passengers leaving an area with an attraction M (i) to an area with an attraction M (j) at a distance x (j) by comparing the probability P (j-1) that passengers from area i will be transported to area j with stop and probability P (j + 1) that passengers will be transported from area i to area j without stop. The total probability will then be expressed as their difference - P (j) = P (j-1) - P (j + 1). Subsequently, it will be possible to work on a modified relationship for determining the number of passengers going from i to j, which additionally contains the variable L (j), which expresses the interval between individual connections between areas i and j. The modified form of the relationship is as follows (4):

$$y(i,j) = \frac{M(i)}{x(j) - L(j)/2} - \frac{M(i)}{x(j) + L(j)/2} \approx \frac{M(i) * L(j)}{x(j)^2} \quad (4)$$

Another modified form of the model is based on identical principles and similar indicators as the gravitational method itself. This is the following form (5):

$$v_{ij} = k * \frac{Q_i * Z_j}{w_{ij}} \quad (5)$$

where:
$v_{ij}$ - traffic flows between areas i a j,
k – gravitational constant, [-]
$Q_i$ – attractiveness (potential) of the i-th starting area,
$Z_j$ - attractiveness (potential) of the i-th final area,
$w_{ij}$ - variable expressing traffic resistance.

The stated form of the model is based on the assumption that the traffic relationship between the areas (Qi and Zj) increases with their size and attractiveness and decreases with increasing so-called traffic resistance (usually represented by travel time or transport distance between areas). The gravitational constant was determined on the basis of research and expert estimates and it expresses a certain territorial characteristic of a given area and within this model it takes values from 0.7 to 0.9. The result of the calculation is then a numerical value, which after the transfer expresses the "relative size" of the transport flow. This form of the model was also used in the research activities of the authors Jánoš and Kříž in their publications focused on transport planning in regional rail passenger transport.

Another modification differs in addition to the different designations of the variables in the numerator of the relationship, but their meaning is not changed. Denominator variable expresses traffic resistance through the transport distance between areas i and j (lij), which is raised to the second power. This form of the formula is as follows (6):

$$v_{ij} = k * \frac{z_i * c_j}{(l_{ij})^2} \quad (6)$$

An alternative to the above modification is to express the transport resistance through the general transport costs (cij) instead of the transport distance (7):

$$v_{ij} = k * \frac{z_i * c_j}{(c_{ij})^2} \quad (7)$$

The best known and the most widespread modification of the Lill model, which is currently the most widely used, is the form used to determine the optimal number of return journeys of all public passenger transport modes between two selected transport points. It takes into account the population of these transport points and the distance between them. The calculated optimal number of journeys (8) is directly proportional to the number of inhabitants of both transport points, the gravitational coefficient K and indirectly proportional to the distance of these transport points. The model has the following shape, the result is always rounded up [10]:

$$j_{1,2} = \frac{A_1 * A_2}{d^n} * K \quad (8)$$

where:
$j_{1,2}$ - optimal number of return journeys (connections) between chosen traffic points,
$A_{1,2}$ – number of inhabitants (in thousands) of the traffic points,
d – transport distance between traffic points [km],
K – gravitational constant (depends on the nature and connection of the selected settlements),
n – variable approaching 2.

### *4.3 New progressive form of the Lill´s gravitational model*

Gravitational models are the inspiration for the creation of the following relationship, which can be considered as a new progressive gravitational method applicable in regional rail transport. The resulting form of the proposed formula for the calculation of the transport potential ($K_p$) can be marked as a further modification of Lill's gravitational model. Its form is as follows (9) [12]:

$$K_p = \frac{\sum_1^n \frac{A_n}{D_n}}{L} \quad (9)$$

where:
$K_p$ – traffic potential coefficient [population/km$^2$],
$A_n$– the number of inhabitants of the n-th seat of the monitored area [piece],
$D_n$– availability of the n-th railway station and stop – its distance from the centre or from its middle [piece],
L– length of the railway passenger transport route [km].

The most significant benefit of the proposed relationship is the assessment of traffict potential and subsequent more efficient identification of bottlenecks on individual regional rail routes, while it is possible to assess whether the line has low transport potential due to low population density or the problem is accessibility of railway stations. and their longer distance from settlements. It is also possible to assess the effectiveness of investments in railway infrastructure on these lines, whether, based on the transport potential, more extensive construction and reconstruction measures will pay off, or operational and organizational measures will be sufficient, etc. Based on the calculated values of Kp on several transport routes, it is possible to better compare these routes and then assess their importance on the basis of the resulting hierarchy and thus the prioritization of possible modernization. Based on scientific opinions and brainstorming methods, the width of the intervals is as follows [12,13].

*Table 1 Determination of the modified intervals width of particular traffic service ranges* [12]

| **Traffic service range** | **The interval of the resulting $K_p$ value** | **Recommended number of pairs of all regional trains** | **Recommended number of seats for all train connections in both directions** |
|---|---|---|---|
| **I.** | 0 – 700 | 4 | up to 500 seats |
| **II.** | 701 – 1 000 | 5 – 6 | 250 – 1 500 |
| **III.** | 1 001 – 1 200 | 7 – 10 | 350 – 3 000 |
| **IV.** | 1 201 – 1 400 | 11 – 15 | 550 – 6 000 |
| **V.** | 1 401 – 1 600 | 16 – 20 | 1 000 – 8 000 |
| **VI.** | 1 601 – 1 800 | 21 – 25 | 2 000 – 10 000 |
| **VII.** | 1 801 – 2 000 | 26 – 30 | 4 000 – 12 000 |
| **VIII.** | 2 001 – 2 500 | 31 – 39 | 5 000 – 15 000 |
| **IX.** | 2 501 – 3 000 | 40 – 49 | 7 000 – 20 000 |
| **X.** | 3 001 and more | 50 and more | 8 000 and more |

## 5 Practical application of the new progressive Lill´s gravitational model

The 3rd chapter contains a practical application of the new progressive Lill´s gravitational model. On the table 2 and table 3 are four model Slovak railway trasport routes (Bratislava–Trnava, Žilina–Čadca, Púchov–Horní Lideč, Plešivec–Slavošovce).

*Table 2 $K_p$ calculation on Slovak railway transport routes Bratislava – Trnava and Žilina - Čadca*

| **Kp calculation on Bratislava–Trnava railway line** | | | | **Kp calculation on Žilina–Čadca railway line** | | | |
|---|---|---|---|---|---|---|---|
| **Tariff point:** | **A** | **D** | **A/D** | **Tariff point:** | **A** | **D** | **A/D** |
| Svätý Jur | 5 700.00 | 1 | 5 700.00 | Brodno | 1 31.,00 | 1.8 | 731,11 |
| Pezinok | 23 002.00 | 0.8 | 28 752.50 | Vranie | 736.00 | 22 | 334,55 |
| Šenkvice | 5 026.00 | 0.65 | 7 732.31 | Rudina | 1 831.00 | 0.8 | 2 288.75 |
| Báhoň | 1 857.00 | 0.55 | 3 376.36 | Kys. N. Mesto | 15 073.00 | 0.7 | 21 532.86 |
| Cífer | 4 321.00 | 1 | 4 321.00 | Ochodnica | 1 933.00 | 1.1 | 1 757.27 |
| Trnava | 65 207.00 | 1 | 65 207.00 | K. Lieskovec | 2 354.00 | 1.3 | 1 810.77 |
| **Total value (A/D)** | | | **115 089.17** | Dunajov | 1 163.00 | 0.23 | 5 056.52 |
| **Transport distance (km)** | | | **46.00** | Krásno n. Kys. | 6 790.00 | 2 | 3 395.00 |
| **Final Kp value** | | | **2 501.94** | Oščadnica | 5 700.00 | 1.7 | 3 352.94 |
| | | | | Čadca | 23 941.00 | 1.3 | 18 416.15 |
| | | | | **Total value (A/D)** | | | **58 675.92** |
| | | | | **Transport distance (km)** | | | **30.00** |
| | | | | **Final Kp value** | | | **1 955.86** |

*Table 3 $K_p$ calculation on Slovak railway transport routes Púchov – Horní Lideč and Plešivec – Slavošovce*

| **Kp calculation on Púchov–Horní Lideč line** | | | | **Kp calculation on Plešivec–Slavošovce line** | | | |
|---|---|---|---|---|---|---|---|
| **Tariff point:** | **A** | **D** | **A/D** | **Tariff point:** | **A** | **D** | **A/D** |
| Dohňany | 1 815.00 | 0.25 | 7 260.00 | Plešivec | 2 282.00 | 0.9 | 2 535.56 |
| Záriečie | 698.00 | 0.7 | 997.14 | Pašková | 349.00 | 0.35 | 997.14 |
| Mestečko | 531.00 | 0.5 | 1 062.00 | Kunova Teplica | 708.00 | 0.6 | 1 180.00 |
| Lúky p. M. | 928.00 | 0.3 | 3 093.33 | Štítnik mesto | 1 550.00 | 0.55 | 2 818.18 |
| Lysá p. M. | 2 093.00 | 0.35 | 5 980.00 | Roštár | 627.00 | 1.7 | 368.82 |
| Strelenka | 439.00 | 0.4 | 1 097.50 | Ochtiná | 544.00 | 0.4 | 1 360.00 |
| Střelná | 596.00 | 0.35 | 1 702.86 | Rochovce | 333.00 | 0.4 | 832.50 |
| Horní Lideč | 1 388.00 | 0.85 | 1 632.94 | Slavošovce | 1 877.00 | 0.4 | 4 692.50 |
| **Total value (A/D)** | | | **22 825.77** | **Total value (A/D)** | | | **14 784.70** |
| **Transport distance (km)** | | | **28.00** | **Transport distance (km)** | | | **24.00** |
| **Final Kp value** | | | **815.21** | **Final Kp value** | | | **616.03** |

Within each specified transport route, the traffic potential is calculated in particular tariff points according to the formula stated in subchapter 2.3. Each tariff point includes the population (A), distance of the railway stop from the town/village centre (D) and finally partial and final value of traffic potential (Kp).

Final Kp values including optimal traffic service range (according to table 1) compared with actual traffic service range is situated in table 3. It follows from the calculated data that optimal traffic service range is IX (40 – 49 pairs of the regional trains during working day) and actual traffic service range in 2020 is VII (35 pairs) on the railway transport route Bratislava – Trnava. It follows that actual traffic service is not sufficient and it is necessary to increase it. Optimal traffic service range on Žilina – Čadca railway line is VII (26 – 30 pairs of the regional trains during working day) and actual traffic service range in 2020 is V (20 pairs). It also follows that it is appropriate to introduce 6 - 10 new pairs of passenger trains. Optimal traffic service range on the railway transport route Púchov – Horní Lideč is II (5-6 pairs of regional trains during working day) and actual traffic service range in 2020 is III (7 pairs). It follows that it is appropriate to introduce 6 new pairs of passenger trains to meet the basic transport needs of passengers. And finally optimal traffic service is I (4 pairs of regional trains during working day) on the transport routes Plešivec – Slavošovce, but at present there is no railway passenger trains. There must be introduced a minimum of 4 pairs of regional passenger trains.

*Table 4 $K_p$ calculation on four model Slovak railway transport routes*

| Railway transport route | Final $K_p$ value | Optimal traffic service range | Actual traffic service range |
|---|---|---|---|
| **Bratislava–Trnava** | 2501.94 | IX | VII |
| **Žilina–Čadca** | 1341.99 | VII | V |
| **Púchov–Horní Lideč** | 815.21 | II | III |
| **Plešivec–Slavošovce** | 616.03 | I | - |

## 6 Conclusion

The current gravitational models used in transport processes, especially in railway passenger transport, are analyzed in the article. The Authors have described and analyzed particular modifications of Lill´s gravitational model. Subsequently, a new proposed modification was introduced. Finally, the practical application of the new model was presented. Within it the authors have calculated traffic potencial (Kp) at five chosen railway transport routes.

Based on the above-mentioned more objective assessment, it would also be possible to estimate more accurately the passenger traffic flows, define bottlenecks of selected transport routes. On this basis, there is a prerequisite for improving the train traffic diagram, linking the different types of transport, increasing the number of passengers, increasing customer satisfaction, as well as a comprehensive improvement and improvement in rail transport that has stagnated in recent years. From the point of view of logistics, the gravitational models and methods should help to find the optimal alternative for moving people with the maximum synergy effect. The main result should be a high-quality logistical chain with satisfied customers [14,15].

Passenger transport logistics can also be solved using other algorithms, as described, for example, in the article [16]. Although the article is focused on the transport of cars, it is worth using the algorithm proposed here also on the problem of passenger transport logistic.

Equally important is the transport of immobile passengers. This is discussed in the article [17]. Within the number of passengers and the number of trains, this would be a restrictive condition in our relationship. On this basis, however, it would be possible to determine the number of barrier-free connections.

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# APPLICATION OF PERIODIC REVIEW INVENTORIES MODEL IN A TYPICAL MEXICAN FOOD COMPANY

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***Keywords:*** inventory management, food Mexican company, periodic review model, perishable products
***Abstract:*** The Mexican family companies must face the challenges of market volatility with greater recurrence, forcing them to use effective tools and models for the proper management of their organizations and inherent activities, such as inventory management. Therefore, this research was carried out at "Moles Santa Monica", a typical food company located in the city of Puebla, Mexico. This enterprise has reflected a high variability in the administration of its inventories, with a Coefficient of Variation (CV) greater than 0.2 in most of their portfolio products. In this way, the objective of this study was to propose an inventory management model that might reduce the shortages and overstock, and also; improves its performance and profitability when it is managed. The applied methods were Pareto and ABC model to choose correctly the best seller company products. The inventory management model chosen was the periodic review (R, S) as well, for being the most effective and the one that best suited the circumstances of the company in question. Three of the portfolio products were studied (MPP10, MPC10 and COP10) due to they are the most representative in incomes and valuables for the company managers. The results allowed us to propose the review periodic model (R), the optimal quantity of units to produce (Q), the safety stock (Ss) and the maximum inventory (S) for each product. We conclude that this model will help the company to face the uncertainty of the demand. Finally, we include limitations and future studies.

## 1 Introduction

Inventory management is one of the most important tasks for any company that produces or manufactures any product or products, and what is looking for is not to have overstock or shortages. These are two of the most common problems in inventory management [1-4]. This situation is not unfamiliar in Mexican family companies, which are immersed in a context of turbulent and changing demand but which, in addition, usually make decisions based on intuition and experience. However, these must be supported by objective and sustained criteria; to avoid permanent conflicts related to excesses and shortages in their inventories.

In order to avoid the prevalence of these conflicts, there are many tools and models that contribute to improving efficiency in inventory management. Such is the case of the periodic review model or known as (R, S), which provides solutions to inventory management problems in different real-life situations where, in addition; under the political framework (R, S) the demand is not constant and there are important variations [4-7]. Those two problems related are disjunctive that the family business Moles Santa Mónica faces; reason why it has been decided to apply the mentioned model.

Furthermore, this model contributes to reduce slow and idle inventories [8]. The essential purpose is to check inventory levels at specific time intervals. It is established that, at the beginning of each of the periods, the inventory levels must first be reviewed in order to immediately determine corresponding replacement; through instantly generated orders [9].

The objective of this study is to propose an inventory model that improves its performance and profitability when managed. This is due to the fact that the family business has gone through a contingency of business succession, along with relocation of the domicile of operations, decrease in sales and turnover of personnel. The research included analysis of documentary information of the company such as: maintenance cost, order costs, financial statements, and sales report, in addition to bibliographic references related to the subject, together with probabilistic models; specifically, the periodic review model.

## 2 Literature review

Inventory management has been studied for researchers and its policies applied in small companies mainly because it involves their financial performance and represents the survival or not of those kinds of companies [10,11]. When they must determine the right quantity of materials and to hold them the correct time in order to avoid associated costs, two typical scenarios emerge: in the first one, companies have too much inventory that represent deterioration, obsolescence, damage and loss [12]; in the second one, shortage of inventory can represent loss of sales, underutilization of the machines, and poor client relations [12,13]. Our study is related with perishable products, due to the company produces typical Mexican food._A comprehensive review of the literature on these products inventory models is available [4,14]. Furthermore, a detailed analysis of the periodic and continuous review model is also available in the literature [15]. Therefore, we briefly summarize the research related to the object of study.

The periodic review model can be used when determining a fixed inventory review and order request time, which means that the inventory management policy must consider the minimum total annual cost, order renewal time, stock of security and the types of inventories; to be able to reduce inventory management costs without affecting the quality of services [8].

Thus, there is a widespread review about optimizing inventory costs with business applications, such as one in which the minimum total cost of inventory is located with a service level of approximately 90%, avoiding in a parallel and considerable way, the shortage. In addition, with the application of the model, significant reductions were achieved in the payment of fines due to penalties; and it is postulated that the use of the policy (R, S) emanates higher storage costs but that by contrast, its management is much easier [4,6,7].

Consequently, the most used practices in the periodic review are policy (R, S) and (R, Q). In the first one, when level "R" is reached, a certain amount is ordered to reach "S"; on the other hand; in the second one, when the point “R” is reached, an order of “Q” size is sent [16].

In addition, there are recent research in which the periodic review probabilistic EOQ (Economic Order Quantity) model is adapted when there is variability in ordering costs, which results in representative savings in logistics cycle costs [17]. There are even other dilemmas presented in the periodic review model, in which the two-item model and two warehouses with transhipment are used; thereby applying heuristics based on greedy and lagrangian relaxation [2,18].

Finally, a stochastic demand periodic review model can be designed considering sudden obsolescence, in which the optimal policy is proposed, and a dynamic programming algorithm is simultaneously proposed to calculate its parameters [19].

## 3 Methodology

To develop this research, the documentation of information was carried out based on the data provided by purchasing, production and sales areas belonging to the company Moles Santa Monica located in the state of Puebla, Mexico. Printed and electronic materials from the mentioned areas were analysed, and a diagnosis of the current situation of the company was made through individual semi-structured interviews with general manager, sales manager and purchasing manager, and in this way being able to know their functioning holistically, understanding their needs according to the context in which the research was conducted. Then, 29 articles that are part of the company's product portfolio were analysed, which represent the mix of products with greater importance for the leaders of the company, by sales and production volume.

Through the use of the ABC method, the most relevant products were defined in terms of sales revenue, according to their rotation between periods from November 2018 to October 2019. Additionally, the three most relevant products were obtained; by means of the Pareto method or 80-20 rule. Finally, the detailed study of demand has been established through the deterministic model of periodic review (R, S).

## 4 Results and discussion

According to the information provided by the managers of this company; where the company has gone through a business succession contingency, along with relocation of the operations domicile, decrease in sales and staff turnover. The Pareto method was used for the 29 articles in the company's product portfolio and those with superlative preponderance were selected. The products were ordered from highest to lowest, taking as a reference the income from sales (Mexican pesos), thereby obtaining; the percentage of contribution (Table 1).

*Table 1 Sales in the period from November 2018 to October 2019*

| Pos | Code | Product name | Total | % of contribution | Accumulated contribution |
|---|---|---|---|---|---|
| 1 | MPP10 | Almondy mole poblano 10 kg | $2,164,694 | 17.8% | 17.8% |
| 2 | MPC10 | Homemade mole poblano 10 kg | $1,338,969 | 11.0% | 28.8% |
| 3 | COP10 | Chicken bouillon 10 kg | $1,219,754 | 10.0% | 38.8% |
| 4 | MPP5 | Almondy mole poblano 5 kg | $976,210 | 8.0% | 46.9% |
| 5 | PPV10 | Green pipian 10 kg | $917,231 | 7.5% | 54.4% |
| 6 | CHL10 | Chili pepper with lemon 10 kg | $794,505 | 6.5% | 61.0% |
| 7 | CHLM10 | Ground chili pepper 10 kg | $600,128 | 4.9% | 65.9% |
| 8 | MPP1 | Almondy mole poblano 1 kg | $542,995 | 4.5% | 70.4% |
| 9 | COP20 | Chicken bouillon 20 kg | $420,626 | 3.5% | 73.8% |
| 10 | PPV5 | Green pipian 5 kg | $391,133 | 3.2% | 77.0% |
| 11 | MPP20 | Almondy mole poblano 20 kg | $387,098 | 3.2% | 80.2% |
| 12 | COP5 | Chicken bouillon 5 kg | $329,072 | 2.7% | 82.9% |
| 13 | MCA10 | Mole poblano sesame seeds 10 kg | $228,634 | 1.9% | 84.8% |
| 14 | CCHMA10 | Chili chamoy 10 kg bag | $182,973 | 1.5% | 86.3% |
| 15 | MPC20 | Homemade mole poblano 20kg | $179,504 | 1.5% | 87.8% |
| 16 | MCA5 | Mole poblano sesame seeds 5 kg | $178,224 | 1.5% | 89.3% |
| 17 | CHB10 | Chili pepper for snacks 10 kg bag | $141,628 | 1.2% | 90.4% |
| 18 | MPCR500 | Almondy mole poblano 0.5 kgs. | $137,264 | 1.1% | 91.5% |
| 19 | PPV20 | Green pipian 20 kg | $132,036 | 1.1% | 92.6% |
| 20 | PPR5 | Red pipian 5 kg bucket | $112,610 | 0.9% | 93.6% |
| 21 | MPP52 | Almondy mole poblano 5 kg bucket | $103,328 | 0.8% | 94.4% |
| 22 | AJM10 | Ground sesame 10 kg bucket | $100,285 | 0.8% | 95.2% |
| 23 | CTL20 | Pickled chipotles 20 kg bucket | $93,301 | 0.8% | 96.0% |
| 24 | MACH10 | Chocolaty mole 10 kg bucket | $90,400 | 0.7% | 96.7% |
| 25 | MPP500 | Almondy mole poblano 0.5 kg | $84,381 | 0.7% | 97.4% |
| 26 | MPSO10 | Spicy mole 10 kg bucket | $79,718 | 0.7% | 98.1% |
| 27 | CTL10 | Pickled chipotles 10 kg bucket | $78,540 | 0.6% | 98.7% |
| 28 | CHLE10 | Special chili pepper lemon 10 kg | $78,198 | 0.6% | 99.4% |
| 29 | MPC5 | Homemade mole poblano 5 kg | $75,301 | 0.6% | 100% |

Based on the table above, ABC products were selected. The statistical property with which the products can be classified in a preliminary way, are those criteria of significant impact on the total value; whether from inventory, sales, or costs [20]. In the study, the classification was determined according to sales in the period indicated above. Thus, 3 classes are presented: Class A: 8 products representing 70.4% of participation; Class B: 11 products that represent 23.3% of sales and finally; Class C: 10 products with a total of 7.4% of sales.

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*Table 2 ABC method*

| Pos | Code | Product name | Total | % of contribution | Accumulated contribution |
|---|---|---|---|---|---|
| **Type A** | | | | | |
| 1 | MPP10 | Almondy mole poblano 10 kg bucket | $2,164,694 | 17.80% | 70.40% |
| 2 | MPC10 | Homemade mole poblano 10 kg bucket | $1,338,969 | 11.00% | |
| 3 | COP10 | Chicken bouillon 10 kg bag | $1,219,754 | 10.00% | |
| 4 | MPP5 | Almondy mole poblano 5 kg bucket | $976,210 | 8.00% | |
| 5 | PPV10 | Green pipian 10 kg bucket | $917,231 | 7.50% | |
| 6 | CHL10 | Chili pepper with lemon 10 kg bag | $794,505 | 6.50% | |
| 7 | CHLM10 | Ground chili pepper 10 kg bag | $600,128 | 4.90% | |
| 8 | MPP1 | Almondy mole poblano 1 kg can | $542,995 | 4.50% | |
| **Type B** | | | | | |
| **Pos** | **Code** | **Product name** | **Total** | **% of contribution** | **Accumulated contribution** |
| 9 | COP20 | Chicken bouillon 20 kg bag | $420,626 | 3.50% | 22.30% |
| 10 | PPV5 | Green pipian 5 kg bucket | $391,133 | 3.20% | |
| 11 | MPP20 | Almondy mole poblano 20 kg bucket | $387,098 | 3.20% | |
| 12 | COP5 | Chicken bouillon 5 kg bag | $329,072 | 2.70% | |
| 13 | MCA10 | Mole poblano with sesame seeds 10 kg bucket | $228,634 | 1.90% | |
| 14 | CCHMA10 | Chili chamoy 10 kg bag | $182,973 | 1.50% | |
| 15 | MPC20 | Homemade mole poblano 20kg bucket | $179,504 | 1.50% | |
| 16 | MCA5 | Mole poblano with sesame seeds 5 kg bucket | $178,224 | 1.50% | |
| 17 | CHB10 | Chili pepper for snacks 10 kg bag | $141,628 | 1.20% | |
| 18 | MPCR500 | Almondy mole poblano micro 0.500 grs. | $137,264 | 1.10% | |
| 19 | PPV20 | Green pipian 20 kg bucket | $132,036 | 1.10% | |
| **Type C** | | | | | |
| **Pos** | **Code** | **Product name** | **Total** | **% of contribution** | **Accumulated contribution** |
| 20 | PPR5 | Red pipian 5 kg bucket | $112,610 | 0.90% | 7.40% |
| 21 | MPP52 | Almondy mole poblano 5 kg bucket | $103,328 | 0.80% | |
| 22 | AJM10 | Ground sesame 10 kg bucket | $100,285 | 0.80% | |
| 23 | CTL20 | Pickled chipotles 20 kg bucket | $93,301 | 0.80% | |
| 24 | MACH10 | Chocolaty mole 10 kg bucket | $90,400 | 0.70% | |
| 25 | MPP500 | Almondy mole poblano 0.500 grs can | $84,381 | 0.70% | |
| 26 | MPSO10 | Spicy mole 10 kg bucket | $79,718 | 0.70% | |
| 27 | CTL10 | Pickled chipotles 10 kg bucket | $78,540 | 0.60% | |
| 28 | CHLE10 | Special chili pepper with lemon 10 kg bag | $78,198 | 0.60% | |
| 29 | MPC5 | Homemade mole poblano 5 kg | $75,301 | 0.60% | |

The names of the products represented by their respective codes, the total sales, the percentage of contribution, as well as the accumulated number of each product are displayed in Table 2 of the ABC method, which is shown above.

Pareto diagram and the ABC model classification are illustrated below (Figure 1).

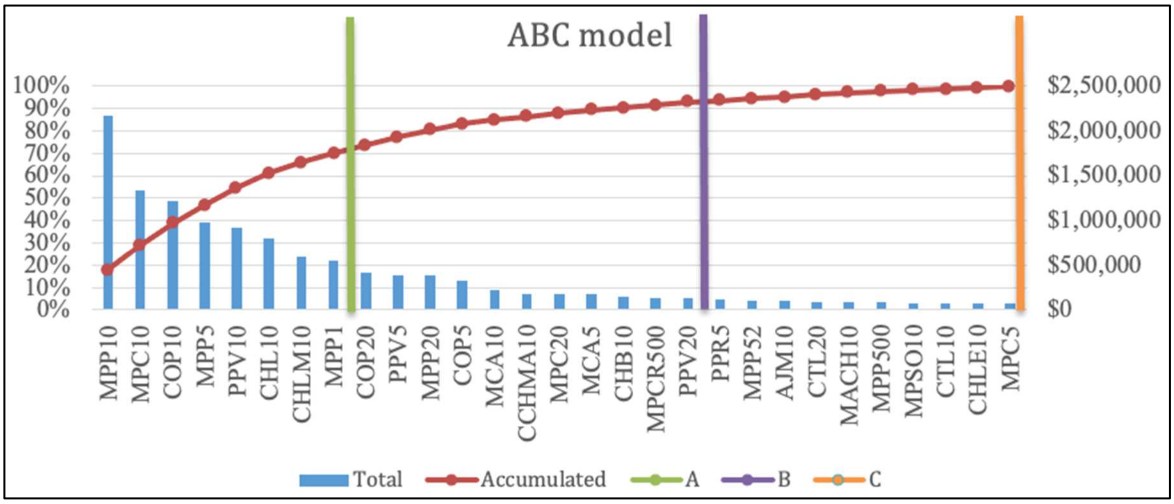

*Figure 1 ABC model classification*

The ABC model classification shown a total of 8 products, representing 70.4% of total sales revenue. For purposes of this study, the 3 most representative type A products of the company were chosen (see Coefficient of Variation) in terms of sales, which are almondy mole poblano almond bucket 10 Kg (MPP10), homemade mole poblano bucket 10 Kg (MPC10) and chicken bouillon bag 10 Kg (COP10).

It was decided to implement the Variability Coefficient (CV) index, for being useful to compare results from the different amount of sales during the study period, where the ratio of the standard deviation to the mean is presented (1). The sales of the selected products are observed for one year; explicitly from November 2018 to October 2019. Calculations of the coefficient of variation were made as follows:

$$CV = \frac{\sigma}{\bar{x}} \tag{1}$$

To start the computation, σ and x̄, were calculated separately. One-year period average sales of selected products was taken. This formula was used [ $\bar{x} = \frac{\sum sales}{n}$]; next the standard deviation sales calculation of selected products was made using [$\sigma = \frac{\sum (x_i - \bar{x})^2}{n}$]. The meaning of every variable is shown below:

- *CV:* Variation relative of the mean,
- *σ:* Standard deviation,
- *x̲:* Total sales average,
- *n:* Number of products in portfolio,
- *xi:* Total amount of sales for each product.

Below is the table corresponding to the Variation Coefficient (CV) of the 29 products. Only the first three products (MPP10, MPC10 and COP10) have a CV <.20, and the rest of the products have a CV> .20. If CV is greater than 0.2, the data is probabilistic, otherwise; they would be deterministic. Therefore, if the sales of the selected products behave like a deterministic demand, the periodic review model is accepted [17].

In this way, it is chosen to work with a periodic review model, since the production of the products requires almost the same type of inputs or ingredients, which means a highly variable demand in the order of the products, which does not allow the use of a continuous review policy. The table of coefficients of variation (CV) is presented below (Table 3).

*Table 3 Coefficient of variation*

| Pos | Code | Product Name | CV |
|---|---|---|---|
| 1 | MPP10 | Almondy mole poblano 10 kg bucket | 0.1724 |
| 2 | MPC10 | Homemade mole poblano 10 kg bucket | 0.1023 |
| 3 | COP10 | Chicken bouillon 10 kg bag | 0.1282 |
| 4 | MPP5 | Almondy mole poblano 5 kg bucket | 0.6362 |
| 5 | PPV10 | Green pipian 10 kg bucket | 0.2283 |
| 6 | CHL10 | Chili pepper with lemon 10 kg bag | 0.3689 |
| 7 | CHLM10 | Ground chili pepper 10 kg bag | 0.8393 |
| 8 | MPP1 | Almondy mole poblano 1 kg can | 0.3577 |
| 9 | COP20 | Chicken bouillon 20 kg bag | 0.3623 |
| 10 | PPV5 | Green pipian 5 kg bucket | 0.4559 |
| 11 | MPP20 | Almondy mole poblano 20 kg bucket | 0.4707 |
| 12 | COP5 | Chicken bouillon 5 kg bag | 0.2210 |
| 13 | MCA10 | Mole poblano with sesame seeds 10 kg bucket | 0.7903 |
| 14 | CCHMA10 | Chili chamoy 10 kg bag | 0.5140 |
| 15 | MPC20 | Homemade mole poblano 20kg bucket | 0.1436 |
| 16 | MCA5 | Mole poblano with sesame seeds 5 kg bucket | 0.7122 |
| 17 | CHB10 | Chili pepper for snacks 10 kg bag | 0.4990 |
| 18 | MPCR500 | Almondy mole poblano micro 0.500 grs. | 0.3179 |
| 19 | PPV20 | Green pipian 20 kg bucket | 0.3009 |
| 20 | PPR5 | Red pipian 5 kg bucket | 0.3861 |
| 21 | MPP52 | Almondy mole poblano 5 kg bucket | 2.0639 |
| 22 | AJM10 | Ground sesame 10 kg bucket | 0.4425 |
| 23 | CTL20 | Pickled chipotles 20 kg bucket | 0.5775 |
| 24 | MACH10 | Chocolaty mole 10 kg bucket | 1.4142 |
| 25 | MPP500 | Almondy mole poblano 0.500 grs can | 0.2774 |
| 26 | MPSO10 | Spicy mole 10 kg bucket | 0.7406 |
| 27 | CTL10 | Pickled chipotles 10 kg bucket | 0.2869 |
| 28 | CHLE10 | Special chili pepper with lemon 10 kg bag | 0.9688 |
| 29 | MPC5 | Homemade mole poblano 5 kg | 0.1984 |

In this research, our model is the simplest according with literature (R, S). The company has a constant and determinist demand of its top three products (MPP10, MPC10 and COP10). The inventory is reviewed every "R" units of time, and "S" represents the maximum level of inventory. We expect that LT is lower than R, that is, the order is coming sooner as the next review. This model is showed in Figure 2.

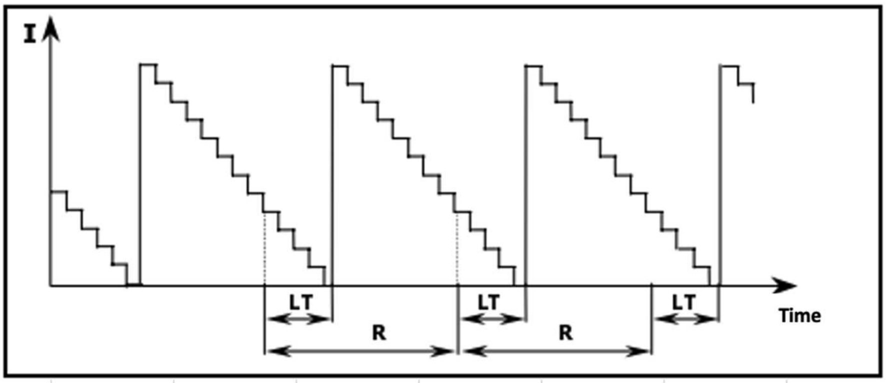


*Figure 2 R, S Constant demand model [21]*

To calculate the batch size with periodic review (Q), it was taken into account that the company carries out an inventory review every month (30 days), and that the delivery time of the most representative and important ingredients according to the Pareto method, have a *Lead Time* (LT) of six days, which represents the number of days that pass, since the order is made, until it arrives. To calculate Q, the following formula (2) was used [16]:

$$Q = \underline{d}(R + LT) + z\sigma_{R+LT} - I \qquad (2)$$

To continue the computation of this formula, the reorder point (R), safety stock (ss) and the probability of depleted inventory was calculated separately. Fist, R was calculated using [$R = \overline{dLT + z(\sigma_{\bar{d}}\sqrt{L})}$]; next, for ss we used [$ss = Z_\sigma(\sigma_{R+LT})$]; finally, the probability was made as fallows [$\sigma_{R+LT} = \sigma\sqrt{R + LT}$]. The meaning of every variable is shown below:

- $\bar{d}$: Average monthly demand,
- ss: Safety stock, which is the deviation of demand during Lead Time plus the review period,
- R: Reorder point,
- *LT:* Lead time of six days,
- $\sigma_{R+LT}$: Vulnerability period Standard deviation,
- *I*: Inventory defined by company.

Using a 95% confidence level proposed for the company, based on the Z score table, we use a data of 1.96. Without subtracting the existing inventory (I), the optimal amount (Q) of inventory, according to the EOQ model, step by step for each of the 3 selected products, are shown next.

*Table 4 Optimal quantity of units to produce*

| Product | Q (units) |
|---|---|
| COP10 | 6316 |
| MPP10 | 6095 |
| MPC10 | 3925 |

Subsequently, the revision period R was calculated. This period indicates the moment in which we must review the current state of the inventory and decide the quantity of products to be manufactured; as shown in Table 5.

*Table 5 Review period for each product*

| Product | R (month) |
|---|---|
| COP10 | 1.56 |
| MPP10 | 1.69 |
| MPC10 | 1.55 |

Consecutively, safety stocks were calculated, according to the following formula, which represents the deviation of demand during *Lead Time* plus the review period, taking into account a service level of 95%.

*Table 6 Safety stock for each product*

| Product | ss (units) |
|---|---|
| COP10 | 2852 |
| MPP10 | 2885 |
| MPC10 | 1859 |

Once you have the safety stock (ss) and the revision period (R), you can determine the target inventory or maximum inventory (S). This is calculated using the following formula (3).

$$S = \underline{d}(R + L) + Z_\sigma(\sigma_{R+L}) \qquad (3)$$

In this policy, it should be remembered that it seeks to support the variability of demand, since it is associated with greater uncertainty. The results represent the maximum inventory (S), calculated in Table 7.

*Table 7 Maximum inventory for each product*

| Product | S (units) |
|---|---|
| COP10 | 7128 |
| MPP10 | 6816 |
| MPC10 | 4431 |

In this way, the inventory policy is completed (R, S); interpreted as a review period (R) and a maximum inventory (S). Table 8; summarizes it below.

*Table 8 Periodic review inventory policy (R,S)*

| Product | Q (units) | Ss (units) | S (units) | R (monthly) |
|---|---|---|---|---|
| COP10 | 6316 | 2852 | 7128 | 1.56 |
| MPP10 | 6095 | 2885 | 6816 | 1.69 |
| MPC10 | 3925 | 1859 | 4431 | 1.55 |

To summarize these results, next figure shows graphically how the model works.

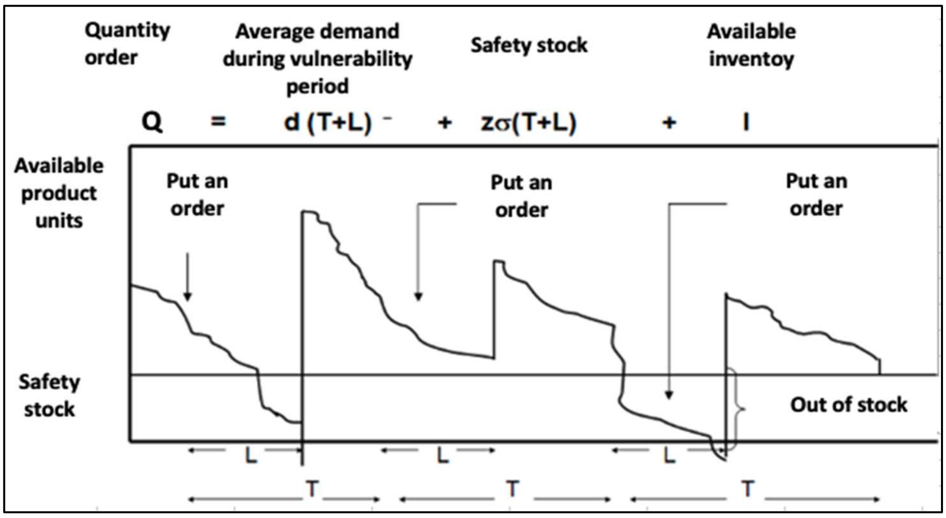


*Figure 3 Graphical periodic review inventory policy*

The results of our research study correspond in the same sense to that described in the literature of previous studies related to the periodic review inventory model, but it also contributes to this theoretical construct when determining which small family companies with limited financial budgets and with raw materials highly perishables, this model might be applied effectively by reducing inventory costs, in addition to reducing shortage problems, better time management in the company's operations and possible penalties by its clients [2,3,7,8,17,22-24].

In the case of our research, it was possible to determine the optimal number of units produced for the products with the greatest variability in demand. In other words, the optimal production quantity for the COP10 product was 6316 units, for the MPP10 it was 6095 units, and for the MPC, it corresponded to 3925 units. This may represent improvements in the way the typical Mexican food company is managed, but it is also a way of preserving the monthly income of the company.

On the other hand, regardless of the level of demand for the typical food company, safety inventories must be guaranteed to continue operating normally. Thus, for the COP 10 product, there must be a safety inventory of 2852 units, while for the MPP10 and MPC10 products, they must have an inventory of 2885 units and 1859 units respectively. In other words, this allows the appropriate amounts to be made while avoiding it, the shortage of products for the company's customers.

Therefore, for Moles Santa Monica company, it will be much easier to make decisions regarding its finished product inventory. For the COP10 product, a maximum inventory of 7128 units must be ensured; the stock will be reviewed every 1.56 months and depending on the level it is at, it must produce enough to reach the quantity associated with the value of “S”. The same must happen with the other two type A products, MPP10 and MPC10; which must have a maximum inventory of 6816 and 4431 units respectively, in review periods of 1.69 and 1.55 months each. If necessary, this policy could be applied to the rest of the company's products. To achieve this, the company will need to improve its business processes and management style.

## 5 Limitations and opportunity areas

Some limitations found was that we only worked with historical data from November 2018 to October 2019. We consider it is necessary in future research to include longer periods of time to determine the statistical behaviour of sales and decide according to the information; the type of model to use.

In another sense, the periodic review model (R, S) could be applied to all the articles handled by the company, however, only the 3 most representative products were considered, so in future studies the periodic review method can be applied for those products that have deterministic demand according to the product catalogue. In addition, another model could be applied for those products whose demand is probabilistic. In this way, a specific planning can be made for each of the products in the company's catalogue.

In future studies, the breakdown of each of the raw materials necessary to produce each type of product can be analysed, since the ingredients necessary to prepare the final products are shared and the reorder values may vary. Other areas of opportunity can be extensive the use of this model to the entire Mexican food company as well as apply the periodic review model to other companies of the same Mexican food industry such as sauces and dips. Even more, it may be interesting to apply it within other family companies with highly perishable inputs; in which the impact of inflation rate must also be included. In addition to the above, a supplementary idea is to explore how management styles impact inventory management, its costs and its logistics cycle.

## 6 Conclusions

With reviewed methodology, it was obtained that critical products have a constant demand, with a behavior that only allows the use of a periodic review model of type (R, S). According to the Pareto 80-20 model, it was possible to choose the most relevant products in terms of sales, which only represent 20% of the portfolio volume, but which, taken as a whole, are equivalent to almost 80% of the production and sale of the company.

The safety stock (Ss) of a policy (R, S) allows to face the uncertainty of the demand during the review period and the lead time. No matter the type of method used for inventory management, the safety stock is essential to have reaction time to any eventuality company can face. Consequently, even Moles Santa Mónica company products have a high variation in their demand, which generates a probability distribution, they can manage their inventories using a fixed monthly review period. According to the results of the model (R, S), a review of finished product inventories will have to be made, which will be subtracted from the lot size obtained with the periodic review model. For this company and other similar SMED's, these activities need to be performed by managers, but represents financial and reputation benefits if the suggested policy is taken into consideration.

The management of orders will be made easier taking into account that fewer orders will be made and the quantity of finished product of type A products will always be available. The time used to place orders could be reduced from four monthly orders placed by the company to one order every 1.56, 1.69 and 1.55 months, for COP10, MPP10 and MPC10 products, respectively; according to the results obtained. The knowledge about the company's work system, as well as the characteristics of its products and having control over the behaviour of demand are crucial to determine inventory policy. In this case, it has its own warehouses, with capital to operate and an accounting system that records purchases and sales.

Finally, although there were limitations in the study, such as those described above, findings about the current conditions of family businesses are essential and need to be made; first to know the current status of the company in terms of warehouse management and second, to determine the type of management they should be carrying out. Today, if small businesses do not apply this type of strategy, they will be closer to disappearance than to prosperity.

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# ANALYSIS OF CONVEYOR DRIVE POWER REQUIREMENTS IN THE MINING INDUSTRY

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***Keywords:*** mining, conveyor, drives, industrial logistics

***Abstract:*** This article presents the analysis of conveyor drive power requirements for three typical mining conveyors. One of the conveyors was found not to be able to start when fully loaded. The analysis indicates that two of the conveyors are adequately powered while one is underpowered. This was found to be primarily the result of the maximum tonnage of the two adequately powered conveyors being 1500 tonnes per hour (TPH) while the inadequately powered conveyor was classed with a maximum tonnage of 1800 TPH. It is recommended that the current draw for each motor when fully loaded be measured. This will be compared to the design. Further analysis was done to allow 2000 TPH on all conveyors. The required upgraded drive size is presented. This article does not address the structural adequacy of the supporting structure. Rather, only the capabilities of the conveyor belt and drives to transport the required TPH.

## 1 Introduction

The mining industry needs bulk material handling process for storage, transhipment, transfer, and transportation functions [1-4]. The bulk items may be ores, sand, gravel, stone, coal, cereals, wood etc. but not limited [5]. The traditional machinery and equipment of bulk material handling systems are truck dumpers, elevators, railcar dumpers, wagon tipplers, ship-loaders, hoppers, loaders classified as stationary and mobile type [6]. The conveyor drives can be used for bulk transporting for almost everything like extracted raw mineral, different mining equipment, worker's goods, and even the mineworkers [7-9]. Diverse conveyor drive and equipment can be found in service in both underground mines and surface mining [10].

The mining industry requires an enormous amount of energy for powering the conveyor drives [11-13]. In the mining industry, the emphasis is placed on improving the energy efficiency of conveyor drive power requirements. Power requirement analysis is essential for improving the conveyor drive energy efficiency in any mining industry [11]. The mining industry must pay enough attention to the conveyor drive power requirements analysis [3,12]. The viability of mining industry operations and future productivity largely depends on the optimization of conveyor drive power requirements. Thus, the associated conveyor drives of the mining industry should be kept tracked and study for conveyor drive energy efficiency. The study should also include the key parameter of the whole drive system to determine the actual power efficiency and suggestions that might help to upgrade the conveyor drive power requirements.

Vast works and research are available for energy optimization and modelling of conveyors drives. The optimization of energy has been done by the researchers for belt drive [9,11,14-15]. Among the available related research, Shirong Zhang et al. [9] worked on the energy efficiency optimization of the belt conveyors. K. P. Shah [14] worked on the belt conveyor for the construction of coal mine drive system, maintenance, and bulk material handling in coal plants that include the power consumption for the different ideal and industrial case. The driving force produced by a single conveyor drive in the mining industry might not satisfy the requirement for material handling in long transport as well as may not be suitable for high speed and heavy drive [11]. Thus, the number of the conveyor drive in the material handling of the mining industry differ based on the amount of bulk materials, hour of service, and operational types.

The logical solution for the above problem of the single drive conveyor is to use a multi conveyor drive [7,11,16-17]. The total power available for conveyor drive can be distributed into the multi conveyor drive of the mining industry that can result in efficient mining production capacity and transport distances [7]. The multi conveyor drives have appeared as convenient for reducing drive system weights and achieving high performance [16]. To use the benefits of a multi conveyor drive, Mukalu Sandro Masaki et al. [16] has analysed and designed a cost-effective belt conveyor drive system for bulk material handling. The study also compares the performance of the multi-drive conveyor with a single drive conveyor based on a previously developed drive system cost optimization model that is reported to have significant cost savings potential.

The operational conditions of the conveyor drive vary on the application of the conveyor drive [4]. Conveyor drive system will be subjected to varying demand and operational conditions throughout its service in the mining industry [4]. The conveyor drive may be engaged for bulk transportation in the upward inclination or downward stepper direction [1,11]. Though the use of the conveyor drive is mainly to transport the extracted mining minerals but needs to meet the different conditions of operations that arise during mining [8]. The sudden operational conditions of the conveyor belt maybe change of motions, overloading, emergency stop and start etc. [18-20].

In some industrial use, multi conveyor drive can suffer from unequal power-sharing. A typical scenario faced by mine sites is that of when there is an emergency stop of a fully loaded conveyor. This is not ideal as restarting can be an issue along with overloading of the conveyor at the loading chute and subsequent spillage. Not being able to restart the conveyor can mean that manual unloading of the conveyor must take place which can take many hours resulting in significant downtime [21].

In the scenario presented in this article, a system of three conveyors was found to have issues with one conveyor not being able to restart when fully loaded. The analysis was done on the three conveyors by Belt Analyst supplied by Overland Conveyor. The required modification for the 15000 TPH drive system has been proposed to upgrade it to 2000 TPH. Necessary key factors have been studied and re-assessed to drive the conveyor system that will eliminate the problem of sudden restarting with a new operating power (kW) supply.

## 2 Methodology

Irrespective of the mining materials, the main operational activities in the solid mining industry are extraction, material transportation, and processing [1-2,9,22]. Among these, the main operating cost of mining largely depends on the material transportation that can reach up to 40% of the mining cost [23-24]. Mining involves bulk materials handling that is not easy to carry and shift by using conventional trucks due to power consumption and fuel price. For deep mining, material transportation becomes more challenging with conventional trucks [22,25]. Thus, mining experts generally rely on designing a transportation mechanism for materials transport at various processing stations of the mining site.

Since mining activities are merely associated with bulk materials handling, conveyor drive turns out to be a widely accepted solution for the miner of the world from the 1800's [8,26]. Initially, the idea of conveyor was for the coal mining industry but now being used for all kinds of the mining industry and in modern manufacturing lines such as in an automobile, agricultural, electronic, food, process, pharmaceutical, chemical, packaging industries [27-28]. It helps to reduce the handling cost drastically and has gain popularity. In the modern iron ore mining industry conveyor systems are an integral part of the transportation system [27-28].

The typical conveyor drive employed in the mining industry is a belt conveyor [2,7-9,23,29]. Belt conveyor is interpreted as a conventional conveyor system consist of two essential components. One is a belt that is allowed to move in a loop passage and the second is two pulleys fixed at either end of the loop. Pulleys are driven by an external power to circulate the belt over the pully roller in the loop continuously. The belt is loaded in one end and unloaded in the opposite end. The conveyor belt arrangement is installed depending on the length of the transportation required, site conditions and material handling rate etc. [2]. Many mining industries install a combination of different types of conveyor drive systems for convenient transportation of the extracted items.

In iron ore fines industries, belt conveyors drive to perform an essential function in nonstop material transport and logistics distributions. The operational cost of it significantly influences the cost of overall mining. All mining companies intend to design an effective drive system that will increase conveyor efficiency and provide reliable service with low maintenance costs [12]. Therefore, it needs an efficient, energy-saving conveyor drive mechanism for transportation in various branches of the industry [30-31]. The energy and drive optimization through the proper fittings of the belt conveyor system can also help and decreasing the number of conveyors [29].

As we know belt conveyor drive uses mechanical power given through pulleys and is mainly sourced by electrical motor drive [9], its energy efficiency can generally be improved by considering the drive's performance, operation, equipment, and technology [32]. S. Zhang et al. [9] used the methodology development to optimize and improve the operational efficiency of belt conveyors. The model proposed by S. Zhang et al. [9] consists of an analytic model collecting all the relevant parameters into four coefficients. The multi conveyor drive can have an effective benefit for optimized transportation in mining [33]. A lot of energy optimization model and case study-based solution is available from the previous research.

C.-H. Lan [33] designed a multi-drive system for the conveyor belt drive transportation system. Assuming a consecutive series of conveyor drives operating without interruption, the optimization considered the material handling, speed of the conveyor to improve the production profit. M. S. Masaki et al. [34] worked on the multi-drive belt conveyors technology to minimizing life cycle costs. The group considered a case study for an extensive simulation model to improve the economic benefit of the drive conveyors. The multiple conveyor drive system tends to affect unbalanced power distribution among the conveyor drives [21]. The uneven power distribution among the conveyor drive causes non-uniformity of material handling phenomenon [18,20,35]. Overall, either single or multi-drive mechanism, the analysis of the power requirement for the energy-efficient drive system is important. Besides this for any up-gradation of the drive system in any mining industry needs a reasonable choice of belt and idlers parameter.

R. Król et al. [36] worked on the determination of the actual efficiency of the power drive system through the analysis of the power requirement for a drive system. Then they compare the input power and actual power used to calculate the efficiency of the drive system. The methodology of power analysis employed for this work has been claimed to be applicable for belt conveyors drive systems which are frequently employed in the underground and surface mining. T. Mathaba et al. [37] worked on the optimization and energy-efficient function of the conveyor belt systems for a cement industry that uses downhill conveyors. A generic energy optimal scheduling model and economic analysis for belt conveyor deriving were anticipated for cost-effective conveyor belt systems.

S. Natalia [22] has discussed the belt conveyor equipment selection, conveying systems, operation, applied mining technology for different kinds of belt conveyors. The author took the concerns of idlers, belt, and drive system as a target of improving the belt conveyor drive efficiency. The conclusions said that the importance of the energy efficiency of belt conveyors and determining parametric relationship for analysis and assessment of energy efficiency of belt conveyors system consisting of 3 belt conveyors with the same volume of material but with different transportation inclination angle [22]. W. Kawalec et al. [29] did the same kind of belt conveyor analysis for technical and organizational improvements of the energy-effective drive system and ecologically friendly operation of the mining drive mechanism. J. Rodríguez et al. [38] worked on commissioning a new drive system for the transportation of ore in the mining industry. The drive system was designed following the requirements of a company. The specific drive systems included drive alternatives that may be utilized in the company and with a control strategy for the drive converters and conveyor belts.

A. Jennings et al. [20] did a case study on a long overland conveyor of Essroc Cement, part of the Italcementi Group, Nazareth plant in Pennsylvania. The complex multi-drive system was observed for control strategy. The starting and stopping strategies of the drive system were also discussed. W. Kung [39] presented a commissioning report of The Henderson Coarse Ore Conveying System. The commissioning deal with the start-up, and operation of the conveyor belt, and mainly power efficiency of the conveyor was critically concentrated for improvement. When the motor drives the conveyor belt some slip occurs especially during starting, sudden load change, and load sharing among the drives [40]. Slip also affect the running characteristics of the belt conveyor. If sufficient power is not provided in the conveyor belt-drive, it may not be able to start.

For a multi conveyor belt drive, all the conveyor belts must be balanced to receive sufficient power for reliable operations. For unpredictable operational conditions like restarting at the fully loaded condition, the conveyor belt drive sometimes fails to restart. To resolve this fundamental operational problem of the belt drive, the functions of the conveyor's key components should be commissioned and upgrade regularly.

## 3 Result and discussion

During commissioning and regular maintenance of the mining industry, we found a multi-drive conveyor belt facing with restarting problem when fully loaded. For the intention of upgrading the conveyor system of that company, we executed a though analysis of the whole mechanism. Three conveyor belts were working in that company to transport iron ore fines. The conveyor profile drawings and datasheets for each conveyor were available. Each conveyor design tonnes per hour (TPH) capacity was known along with the properties of the material being transported, the horizontal and vertical pulley centre distances, the details of the carry and return idler sets, the belt details, the drive details, and the counterweight mass [41]. From these inputted details, the belt speed, belt capacity, DIN and drive power requirements were calculated. Both inputted and calculated values are presented in Table 1 below.

The conveyor belt “A”, “B” and “C” was loaded with 1800 TPH, 1500 TPH, 1500 TPH of iron ore fines. The centre distance for conveyors “A”, “B”, and “C” were 274, 247, and 89 m respectively with a vertical inclination of 18, 11, and 17 m between the start and endpoints. The long conveyor “A” had a conveying speed of 2.2 m/s and “B” and “C” had an equal speed of 1.8 m/s, slightly lower than the belt “A”. The speed was calculated from the operations.

All three C6 CEMA type belts were at 35° carry idler angle with side spacing of 1.2 m. The return side spacing is 3 m for the same type of CEMA placed at 0° return idler angle. The belt width for three conveyors is 900 mm with 10 mm top cover thickness, 4 mm bottom cover thickness and reported to have 81.9%, 82.1%, and 82.1% belt capacity. The calculated demand power for the belt drives is 164 kW, 88 kW, and 94 kW. It indicates that the drive “A” is overpowered, and drive “B” and “C” are underpowered with respect to their designated power (Table 1).

As can be seen, although the belt capacity of all three conveyors is less than 100%, the calculated demand power for conveyor “A” is more than the drive nameplate power. As such, when fully loaded, the conveyor would not be able to run, let alone start when there is a higher demand for power to enable all idlers to start rotating and to overcome any settling of the idler into the belt due to the weight of the product. It is recommended that the drive power amperage be measured on the conveyors to confirm that the analysis matches real-world measurements.

*Table 1 Inputted and Calculated values for conveyors (current)*

| Conveyor (current) | Inputted / Calculated | A | B | C |
|---|---|---|---|---|
| TPH | Inputted | 1800 | 1500 | 1500 |
| Material | Inputted | Iron ore fines | Iron ore fines | Iron ore fines |
| Horizontal centre distance (m) | Inputted | 274 | 247 | 89 |
| Vertical centre distance (m) | Inputted | 18 | 11 | 17 |
| Belt speed (m/s) | Calculated | 2.2 | 1.8 | 1.8 |
| Carry idler angle (°) | Inputted | 35 | 35 | 35 |
| CEMA type | Inputted | C6 | C6 | C6 |
| Carry side spacing (m) | Inputted | 1.2 | 1.2 | 1.2 |
| Return idler angle (°) | Inputted | 0 | 0 | 0 |
| CEMA type | Inputted | C6 | C6 | C6 |
| Return side spacing (m) | Inputted | 3 | 3 | 3 |
| Belt capacity (%) | Calculated | 81.9 | 82.1 | 82.1 |
| Belt width (mm) | Inputted | 900 | 900 | 900 |
| Carcass | Inputted | PN1250/4 | PN1250/4 | PN1250/4 |
| Cover compound | Inputted | AS-A | AS-A | AS-A |
| Top cover thickness (mm) | Inputted | 10 | 10 | 10 |
| Bottom cover thickness (mm) | Inputted | 4 | 4 | 4 |
| DIN | Calculated | .0233 | .0212 | .0262 |
| Counterweight (kg) | Inputted | 7550 | 10000 | 6000 |
| Drive nameplate power (kW) | Inputted | 150 | 110 | 110 |
| Calculated demand power (kW) | Calculated | 164 | 88 | 94 |

*Table 2 Inputted and Calculated values for conveyors (upgraded)*

| Conveyor (upgrade) | Inputted / Calculated | A | B | C |
|---|---|---|---|---|
| TPH | Inputted | 2000 | 2000 | 2000 |
| Material | Inputted | Iron ore fines | Iron ore fines | Iron ore fines |
| Horizontal centre distance (m) | Inputted | 274 | 247 | 89 |
| Vertical centre distance (m) | Inputted | 18 | 11 | 17 |
| Belt speed (m/s) | Calculated | 2.6 | 2.6 | 2.7 |
| Carry idler angle (°) | Inputted | 35 | 35 | 35 |
| CEMA type | Inputted | C6 | C6 | C6 |
| Carry side spacing (m) | Inputted | 1.2 | 1.2 | 1.2 |
| Return idler angle (°) | Inputted | 0 | 0 | 0 |
| CEMA type | Inputted | C6 | C6 | C6 |
| Return side spacing (m) | Inputted | 3 | 3 | 3 |
| Belt capacity (%) | Calculated | 77 | 77 | 74.2 |
| Belt width (mm) | Inputted | 900 | 900 | 900 |
| Carcass | Inputted | PN1250/4 | PN1250/4 | PN1250/4 |
| Cover compound | Inputted | AS-A | AS-A | AS-A |
| Top cover thickness (mm) | Inputted | 10 | 10 | 10 |
| Bottom cover thickness (mm) | Inputted | 4 | 4 | 4 |
| DIN | Calculated | .0230 | .0211 | .0256 |
| Counterweight (kg) | Inputted | 7550 | 10000 | 6000 |
| Drive nameplate power (kW) | Inputted | 210 | 150 | 150 |
| Calculated demand power (kW) | Calculated | 184 | 120 | 127 |

Balancing out all three conveyors on 2000 TPH was analysed in order to recommend what sort of drive upgrade would be required and to ensure that the existing belt would be able to cope with the potential increased capacity. All inputted data was identical except the desired upgraded TPH (Table 2). Drive power was increased in common commercially available increments until the drive power exceeded the calculated required drive power.

The analysis revealed that an increase on all three conveyors' drives was required in order to enable a throughput of 2000 TPH through the system of three conveyors while still maintaining a belt capacity of less than 100% (77%, 77%, and 74.2%). In the proposed upgraded design, the calculated belt speed for conveyor "A" become increased by 18.18 %, and for "B" and "C", the speed increased by 44.44% and 50% respectively. There was no change considered and suggested for the belt types and counterweighted. The DIN of the conveyor changes slightly and the proposed power for the drive system has 15~25% clearance to run upgraded 184 kW, 120 kW, and 127 kW drives.

The underlying structure must be analysed to determine if any changes there need to be made. As mentioned, the actual drive amperage should also be measured and compared to the analysis before any upgrade is carried out (Table 3).

*Table 3 Summary of current and upgraded drive requirements*

| Conveyor | Current (kW) | Proposed (kW) |
|---|---|---|
| A | 150 | 210 |
| B | 110 | 150 |
| C | 110 | 150 |

## 4 Conclusions

Material handling and transportation cause a substantial amount of costs in the mining industry. Regular commissioning, up-gradation, and power optimization become essential with such a phenomenon. This article presents the analysis of conveyor drive power requirements for three typical mining conveyors. One of the conveyors was found not to be able to start when fully loaded. The analysis indicates that two of the conveyors are adequately powered while one is underpowered. This was found to be primarily the result of the maximum tonnage of the two adequately powered conveyors being 1500 tonnes per hour (TPH) while the inadequately powered conveyor was classed with a maximum tonnage of 1800 TPH. It is recommended that the current draw for each motor when fully loaded be measured. This will be compared to the design. Further, the analysis was done to allow 2000 TPH on all conveyors. The required upgraded drive size is presented. This article does not address the structural adequacy of the supporting structure. Rather, only the capabilities of the conveyor belt and drives to transport the required TPH.

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# SUSTAINABLE HUMAN RESOURCE MANAGEMENT AND GENERATIONS OF EMPLOYEES IN INDUSTRIAL ENTERPRISES

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***Keywords:*** generational groups, industrial enterprises, performance, remuneration, rewards
***Abstract:*** Sustainable human resource management is one of the distinguished approaches for ensuring the organizational performance of an organization in today's turbulent business environment. Human resource management ensures the achievement of the organizational goals through practices of managing human resources. Sustainable human resource management thereby ensures the development and maintenance of the potential of all employees in the organization. The main goal of this paper is to present the results of research in the field of human resource management with respect to different generations of employees in industrial enterprises operating in the Slovakia. The research sample consisted of n = 1 471 respondents (employees of industrial enterprises). The most important results of the prezented research is the finding that employees of industrial enterprises consider work performance, which influences their remuneration, to be important. The research showed that there are statisticaly significant relationships between employees at managerial and production positions and the perceived importance of work performance when determining the income of managers and production employees ($r_s$ = 0.274 and $r_s$ = 0.363).

## 1 Introduction

The first chapter of the paper consists from two parts. The first part provides insight to the literature and previous studies in the field of sustainable human resource management, partially performance of employees and their remuneration. The second part is devoted to a brief description of the individual generations of employees with respect to the analysed issues.

### *1.1 Sustainable human resource management and performance of employees*

Sustainability is a long-term focused approach to business. It represents the creation of such systems and processes that are able to endure into long time work. Given that businesses have their economic nature but operate within certain environments and social systems, the study of sustainability is not limited to the environmental issues. The three key dimensions in which sustainability needs to be studied are economic, ecological but also social [1]. Sustainability is not just a trend, but a topic in management of industrial enterprises, that should be seriously addressed [2]. By adopting the principles of sustainability, organizations can become more profitable and maintain their activities in the long run. The sustainable approach to management of organizations represents a processes in which organizations integrate their economic, environmental and social goals into their business strategies and optimize the balance between all three interconnected dimensions. Sustainability is about building a society in which the right balance is maintained between economic, environmental and social goals in the long term. For organizations, this means not only maintaining and expanding economic growth and shareholder value, but also adopting and adhering to ethical business practices, creating sustainable job positions, creating value for all stakeholders and caring for the needs of insufficiently secured workers [3]. Given the importance of employees for the success and performance of the organization, it is necessary for the management of organization to implement sustainability into human resource management processes [4]. Sustainable Human Resource Management (SHRM) supports the conditions for the sustainability of organizational workforce. It develops the sustainability of the workforce by improving the ability of human resource management processes to continuously attract new employees, regenerate the workforce by caring for its employees, and support employees to be motivated and committed. Through targeted management of human resources processes, it ensures sustainability by, on the one hand, making the human resources management system itself sustainable. On the other hand, sustainable human resource management contributes to the sustainability of enterprises by reconciling economic, environmental, social and human sustainability objectives [5].

Improving the performance of organizations does not only depend on the characteristics of employees, such as their assumptions, abilities or competencies, but also on how the management is uses them, and this depends on human resource management practices in the organization [6]. From the point of view of the sustainability of business performance, it is, among other things, important to maintain the employability of employees [7], as well as their motivation and retention. In the productive population, many working days are lost due to illness. This represents a huge cost in terms of staff shortages and weakened economic performance. As we can see, the social, economic and environmental aspects are interlinked and form feedback loops [8]. Therefore, it is important to monitor which working conditions affect the health of employees, well-being but also social and family life [9]. Workplace stress also affects if employees feel they have a lot more work than their colleagues or feel that their efforts are not appreciated or adequately rewarded [10]. Recognition, trust, fair treatment and support contribute to motivation and improve not only workplace well-being but also work ability [11]. Employees of all ages are shaped by their own life experiences. Naturally, older employees had more opportunities to survive more events that could affect their attitudes. Age can therefore be one of the reasons for different values or attitudes, also to the work [12]. Usually, more than one generation of employees meet and cooperate at the same workplace. Each generation can manifest different values, attitudes to work and motivational preferences [13,14]. However, there is no absolute exactness in limiting the years of birth of individual generations. In order for remuneration for work to be motivating for employees, it is important that it takes into account their work values and work motivation, which can be differentiated individually, which is given by the uniqueness of individuality of each person. However, some research and studies confirm that the preferred remuneration for work may be different for different generations of employees. Employee preferences and individual preferences can be influenced by a person's value system, his attitudes, interests, life situation, but also by the life stage or age of the employee.

### *1.2 Generational groups of employees*

The post-war generation, sometimes referred to as "Baby boomers", is considered to be people born in 1946-1960, the next Generation X, born in 1961-1980, Generation Y born in (1981-1995) and Generation Z, born in 1995- 2009. The youngest generation born since 2010 is often referred to as the Generation Alpha. Members of each generation show certain characteristics, different values are essential for them, they have different approaches to work and motivational preferences. For the post-war generation, money is an important motivating factor, along with title, recognition and respect [15]. Compared to the post-war generation, Generation X, and in particular Generation Y, value leisure time more strongly and attach more value to work providing external rewards. Generation Y also values internal and social rewards less than the post-war generation. It is also pointed out that Generation Y prefers external rewards (external motivation) more than the post-war generation, not wanting to work hard but still wanting more money and a higher position [16]. Older employees could be offended when younger ones demand more responsibility or higher salaries during job interviews. According to them, these requirements are not always the result of an exaggerated ego, but of a market economy. As most of the workforce will be entitled to retire, young workers will become a much in request in the next decade. If the organization does not offer higher salaries and more engaging work for young employee, another organization will do so. Understanding these types of pressures is key to promoting strong intergenerational communication [17]. Generation X attaches little value to their things, they do not consider them part of their value system. While the materialistic person will stick to the property, this generation is more willing to get rid of it and replace it with a new and improved version. This means, for example, that they do not stick to their house or home as their parents and are more willing to replace it for a better quality of life or work [18]. Generation X employees are looking for a work-life balance and are motivated by work that satisfies them personally and financially. For them, money is a reward for a job well done, but they do not accredit value to that work. They appreciate the remuneration in the form of extra days off, which will allow them to improve their work-life balance. For Generation Y, friendship is such a strong motivator that Generation Y workers choose a job just to be with their friends. They have a sense of ethics and participate in justified activities. As with Generation X, money is an important but not separable factor for them [15]. Generations X and Y prefer work-life balance over the post-war generation, which saw sacrificing personal life for work as a price to pay for success [19]. The Millennium Generation Y focuses on finding work that is stable, preferably resilient to recession, and paid enough to pay their bills and save. As soon as they find one, they would rather stay in it. Their reluctance to take risks influences their decisions in the sense that while other work may be more interesting to them, this does not mean that it is in their best long-term interest [20]. Generation Z is very responsive to clearly defined and directly calibrated rewards for spent time or performed tasks. The most effective way to maintain existing working relationships with Generation Z and manage their performance is for managers to clearly discuss performance with them and to reward transparently on an ongoing basis [21].

Demographic developments in Slovakia and the European Union suggest that organizations should take into account the age structure of employees when ensuring sustainable human resource management. From the point of view of future development, in addition to age diversity, it is also necessary to take into account the prognosis of the population aging [22-25]. Demographic trends and an aging population have become an emerging topics, mainly due to the impact of their effects. Given this, their are important not only from a social and health point of view, but also because of its economic context [26]. A comprehensive analysis of the issue of population aging brings more robust results that can be of great importance for decision-making processes in several areas of the decisive sphere. These are, in particular, labour market policies, the relationship between the burden on the economically active population and economic growth or social cohesion [27]. Several trends affect labour shortages. The number of the post-productive population is increasing, and the prevalence of chronic diseases is also increasing [28]. In recent years, skilled young people leaving for work that does not match their qualifications have also contributed to labour shortages. This characteristic type of migration has caused an accumulation of skills shortages due to the negative demographic trend in the Slovak Republic [29].

## 2 Methodology

The next part of the paper is devoted to the description of the research problem, the definition of the main goal of the research, the results of which are presented in the submitted paper. Next, there are defined established research question and research hypotheses, the method of data collection and the data collection tool, and finally, there is described the research sample.

### *2.1 Reserach problem and research goal*

The main research problem is defined in the field of human resource management in industrial enterprises in Slovakia, dealing with the remuneration of employees on the basis of work performance. As already mentioned, the importance of remuneration and the preference for the form of remuneration may vary from employee to employee, and the degree to which individual needs are met affects the employee's well-being, mental well-being, or even health to varying degrees. Remuneration of employees is largely dependent on the nature of the work performed (job position), but it is also significantly affected by the work performance achieved. A common problem can be the perception of employee remuneration for work performance, which results from the subjective perception of an employee from a particular generation. Due to the fact that there are currently four unique generations of employees working on the labour market [21,29,30]. It is important to examine the conditions and used approaches of human resource management in industrial enterprises in Slovakia for the purpose of sustainable human resource management development.

Based on the analysis of the theoretical outcomes and the definition of the research problem, we can state that the research in the field of employee performance and remuneration is defined in two relationships, which are shown in Figure 1.

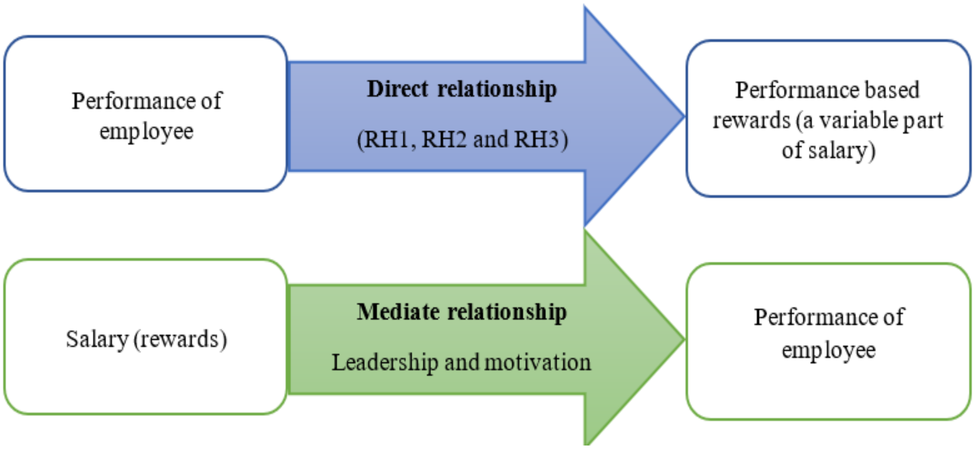


*Figure 1 Research framework (source: own elaboration, 2020)*

As shown in Figure 1 above, the mediated relationship between salary (remuneration for work performed) and employee performance has been supported by several studies [31-33], which emphasize the importance of leading people and the aim-oriented motivation. The relationship is conditioned on reward system based on performance. At the same time, it is important to emphasize that employees may lose the motivation to perform quality work, because their evaluation depends on the quantity of work performed. The research presented by the authors of the paper dealt with the direct relationship where the relationships between the performance of employees in various job positions and their salary evaluation were proved through established research hypotheses.

**The main goal of the research** was to examine the sustainable management of human resources in industrial enterprises in the Slovak Republic with regard to employees from different generations.

**The research problem** is concretized through defined research questions, on the basis of which research hypotheses were established.

**RQ1:** How do employees of different generations perceive the importance of work performance in determining the income of employees in at different job positions?

**RH1:** There is a statistically significant relationship between managerial positions and the perceived importance of work performance in determining managers' incomes.
**RH2:** There is a statistically significant relationship between production jobs and the perceived importance of work performance in determining the income of production employees.
**RH3:** There is a statistically significant relationship between administrative jobs and the importance of work performance in determining the income of administrative staff.

## *2.2 Data collection tool, data collection and description of the research sample*

The collection tool was statistically evaluated as valid and reliable, as evidenced by the fact that the Crombach alpha coefficient = 0.83, which can be considered sufficient for scientific purposes [34]. The research questionnaire contained 8 questions, the first 5 questions are socio-demographic (self-governing region in which the organization operates, number of employees, gender, job position and year of birth), the other 3 questions focused on the perceived importance of work performance in determining employee income at various job positions (managerial, production, administrative and others). The questionnaire was anonymous, the only identifiers were the age and gender of the respondents.

Data collection within the research was carried out by physical distribution of the collection tool, which was distributed to employees of different ages and in different job positions. Distribution was carried out in all eight self-governing regions of the Slovak Republic in the period from September 2018 to January 2019. The research sample consists of n = 1 471 respondents (employees of industrial enterprises). Figure 2 shows the percentage of respondents according to their affiliation to a particular generation.

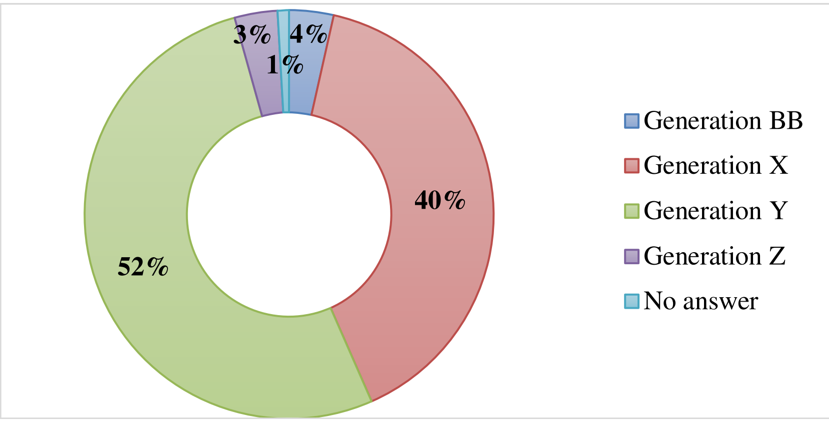


*Figure 2 Respondents by generational groups in percentages (source: own elaboration, 2020)*

Figure 2 shows that most respondents were 770 employees of industrial enterprises from generation Y (52.35 %). The lowest number of respondents was from the generation Z, they are represented by 50 employees of industrial enterprises (3.39 %). The stated percentages are approximately in the same percentage as the individual generations present on the labour market [23]. As can be seen in Figure 3, respondents were also divided according to their current job position. Most respondents hold administrative and specialized jobs, 631 employees (42.90 %). The second largest group in the research sample is represented by production workers in the number of 549 (37.32 %). The third group consists of respondents who work at managerial positions, the group consists of 272 respondents (18.46 %). The last group consists of respondents who did not state what job position currently work at, 19 respondents (1.29 %).

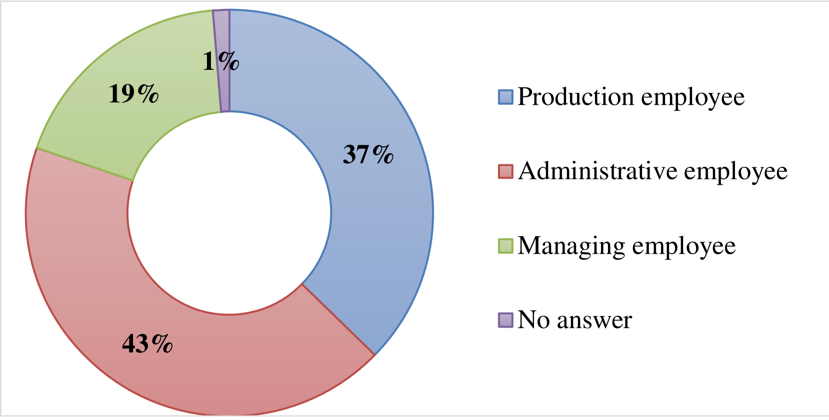


*Figure 3 Respondents by job position (source: own elaboration, 2020)*

Figure 3 shows the structure of respondents by job position. The structure of respondents according to the job position allows to compare the results within individual groups of respondents.

## 3 Results and discussion

The next part of the paper is devoted to the evaluation of established research questions and research hypotheses and a discussion of the most important findings in the research. The evaluation of the research question and research hypotheses was performed in the MS Excel program and in the SPSS 22.0 program (Statistical Package for the Social Sciences) from IBM.

**RQ1:** How do employees of different generations perceive the importance of work performance in determining the income of employees at different job positions?

For a better presentation of the results, we divided the results into three tables (Table 1, Table 2 and Table 3), which contain the perceived importance of work performance according to individual generations for particular job position categories. The results considering managerial job positions are shown in Table 1 below.

*Table 1 Perceived importance of work performance according to different generations of employees in determining managers' incomes (source: own elaboration, 2020)*

| Generation / Evaluation | 1 – not at all | 2 - partially | 3 – significantly | No answer | Sum |
|---|---|---|---|---|---|
| **Generation BB** | 8 | 20 | **24** | 0 | 52 |
| **Generation X** | 72 | **283** | 226 | 5 | 586 |
| **Generation Y** | 89 | **392** | 280 | 9 | 770 |
| **Generation Z** | 4 | **28** | 18 | 0 | 50 |
| **No generation assigned** | 3 | 6 | 3 | 1 | 13 |
| **Sum** | 176 | 729 | 551 | 15 | **1471** |

As can be seen from Table 1, it can be stated that up to 729 respondents (49.56 %) think that work performance has only a partial effect on managers' incomes. According to employees of industrial enterprises without affiliation to the generation, up to 551 respondents (37.46 %) think that the work performance of managers has a significant impact on their income and only 176 employees of industrial enterprises (11.96 %) think that work performance has no effect on the income of managers. Based on the partial results, we can say that there is a difference in perception between the Baby boomer's generation and other generations of employees. Managerial positions are generally associated with higher revenues than for other job positions. However, linking managers' performance and remuneration can be difficult if their performance goals are not clearly defined. The significance of the reward may change as the general conditions change, regardless of the pressure on performance. Managers with high abilities are characterized by a high knowledge of the environment in which they operate. Especially in times of financial crisis, high-capacity managers focus on maintaining reputation, less risky opportunities and lower incomes [35].

Table 2 shows the analysed results of the perceived importance of work performance on income in production jobs. Individual results are divided according to the affiliation of respondents to individual generations.

*Table 2 Perceived importance of work performance according to different generations of employees in determining the income of production employees (source: own elaboration, 2020)*

| Generation / Evaluation | 1 – not at all | 2 - partially | 3 – significantly | No answer | Sum |
|---|---|---|---|---|---|
| **Generation BB** | 7 | 16 | **28** | 1 | 52 |
| **Generation X** | 42 | 202 | **333** | 9 | 586 |
| **Generation Y** | 44 | 308 | **407** | 11 | 770 |
| **Generation Z** | 1 | 20 | **28** | 1 | 50 |
| **No generation assigned** | 1 | 5 | 6 | 1 | 13 |
| **Sum** | 95 | 551 | 802 | 23 | **1471** |

Based on the results shown in Table 2, it can be stated that up to 802 respondents (54.52 %) think that the work performance has a significant impact on determining the wages of production employees. The second largest group of answers is that work performance is partly important in determining the income of production employees 551 (37.46 %) and only 95 respondents (6.46 %) think that the work performance is not important in determining the income of production employees. Based on the above, we can say that the work performance of production employees is still dominant in determining the amount of their earnings. Performance-based remuneration can be motivating for workers by giving the worker a sense of control over the amount of his or her remuneration. On the other hand, performance-based rewards can create stress responses that can have an impact on employees' health. Stress is indicated especially for certain types of reward systems based on performance, such as piece rate pay. The dependence of rewards on performance has an positive impact on the quantity of production, but not on the quality of the services provided [36]. When comparing the results, it was shown that there are no differences in the assessment of the impact of the achieved performance on the income of employees of industrial enterprises from different generations. The results of the evaluation of the last third partial part of the established research question can be seen in Table 3, which is shown below.

*Table 3 Perceived importance of work performance according to different generations of employees in determining the income of administrative and other employees (source: own elaboration, 2020)*

| Generation / Evaluation | 1 – not at all | 2 - partially | 3 – significantly | No answer | Sum |
|---|---|---|---|---|---|
| **Generation BB** | 8 | **26** | 18 | 0 | 52 |
| **Generation X** | 94 | **289** | 186 | 17 | 586 |
| **Generation Y** | 101 | **409** | 242 | 18 | 770 |
| **Generation Z** | 10 | **22** | 18 | 0 | 50 |
| **No generation assigned** | 3 | 6 | 4 | 0 | 13 |
| **Sum** | 216 | 752 | 468 | 35 | **1471** |

As can be seen in Table 3 above, according to the respondents, work performance is only partially important in determining the income of administrative and other employees 752 (51.12 %). The second most numerous answers were that work performance is important, 458 respondents (31.82 %) marked this answer. Lastly, respondents indicated the answer that work performance is not important at all in determining the income of administrative and other employees 216 (14.68 %). We reiterate that there is no difference between the responses of employees of different generations. Furthermore, we can state that this answer was most often marked for administrative and other job positions. For example, the negative impact of performance-based remuneration has been demonstrated for university staff. It has been shown that if remuneration was based on experience and productivity, this led to a lower level of satisfaction in the long run and a lower level of cooperation, especially with a large range of remuneration depending on performance [37]. Research has shown that human resource management plays an important role in performance-based remuneration by ensuring and emphasizing clarity and consistency in what employees are expected to do and on the basis of which the remuneration is awarded [38,39]. When evaluating the research results, we focused on the perception of differences with respect to different generations or job positions of employees. We did not focus on gender differences in the perception of differences between the remuneration of employees based on their work performance in presented research. Other research has confirmed some gender differences, for example it was confirmed that the basic wage is more important for women than for men [40].

**RH1:** There is a statistically significant relationship between managerial positions and the perceived importance of work performance in determining managers' incomes. The mentioned variable correlates at the level of sig = 0.05 with the value of the Spearman correlation coefficient rs = 0.274. The value of significance reached the required level (sig <0.05), therefore we do not reject the above alternative hypothesis and we can confirm that there is a weak correlation between the analysed variables.

**RH2:** There is a statistically significant relationship between production jobs and the perceived importance of work performance in determining the income of production employees. The mentioned variable correlates at the level sig = 0.10 with the value of Spearman's correlation coefficient rs = 0.363. The value of significance reached the required level (sig <0.10), therefore we do not reject the above alternative hypothesis and we can confirm that there is a moderately strong correlation between the analysed variables.

**RH3:** There is a statistically significant relationship between administrative jobs and the importance of work performance in determining the income of administrative staff. The mentioned variable correlates at the level of sig = 0.05 with the value of the Spearman correlation coefficient rs = 0.094. The significance value reached the required level (sig <0.05). The analysed relationship is statistically significant, but with a very low to negligible value of the correlation coefficient. Based on the above, we reject the alternative hypothesis H3 and confirm the null hypothesis H0. Therefore, we can argue that there is no statistically significant relationship between administrative jobs and the importance of work performance in determining the income of administrative staff.

## 4 Conclusion

Research presented in the paper has shown that employees of industrial enterprises at various job positions perceive work performance equally important in determining the income of production and administrative employees. The only exception is the perception of employees of different generations in determining the income of employees at managerial positions. All findings can be used in application of the sustainable human resource management, because clear, transparent and fair remuneration is not only a significant motivating factor. It also affects the perception of the employer as socially responsible and fair, which affects not only the relationship of employees to the employer but also the reputation of the employer in society and in the labour market. The perceived importance of the achieved work performance in the remuneration of employees from different generations has a significant influence on motivating and the perception of the employer's approach to fair treatment of employees at various job positions.

Employers should focus on improving human resource management processes with an emphasis on employee care to ensure a sustainable workforce that affects not only the individual but also the overall performance of the organization. It should be clear from the human resource management priorities, which activities and how they are aimed at improving human resource management processes. These should ensure the improvement of the sustainability of human resources by increasing satisfaction and thus the willingness to perform and retain in the organization, which, by focusing on securing and maintaining the employability of employees through prevention and health protection.

The authors of the paper will continue in further research and expand their results by examining the factors influencing the priorities of human resource management in industrial enterprises. In their further research, they will focus on the impacts of the introduction of Industry 4.0 and pandemic measures on industrial enterprises, on human resource management in industrial enterprises and disadvantaged employees. Sustainable human resource management is focused on human resource management in the long run. Given the huge changes that industrial companies have to deal with, this issue is very topical and it is desirable to address it in further research.

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# AUTOMATIC IDENTIFICATION SYSTEMS FOR MANAGEMENT - MATERIAL FLOW CONTROL AND STOCK STATUS

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***Keywords:*** RFID, RFID system, smart logistics, automatic identification
***Abstract:*** The subject of the article is to define the current state of the information system, to describe the use of technology in practice and to understand the principle and benefits of smart logistics. To describe the operation of RFID technology and systems that are necessary for the effective operation of a comprehensive automatic identification system. The issue is to define the current state of information technology and create a project for automatic identification. The aim of the smart logistics project is the overall improvement of the production process, registration of parts and the overall highlighting of the company's reputation. Automatic identification systems are nowadays one of the fastest growing areas, whether information logistics or logistics as such. Manufacturing companies are trying to apply more and more elements of these systems to their production processes. Slovak companies, which have their production process based on international orders, are increasingly trying to optimize their production and thus approach Western countries in the field of automatic identification and registration of parts.

## 1 Introduction

Automatic identification systems are nowadays one of the fastest growing areas, whether information logistics or logistics as such. Manufacturing companies are trying to apply more and more elements of these systems to their production processes. Slovak companies, which have their production process based on international orders, are increasingly trying to optimize their production and thus approach Western countries in the field of automatic identification and registration of parts.

Many leading authors in the logistics and transport sector are dedicated to the areas of RFID technology, with which logistics information systems are closely related and their functionality. They speak of the correct and efficient functioning of the logistics system, of which the logistics information system is a part, as a set of consecutive activities. If one of these activities does not work properly, the proper and efficient operation of not only the information logistics system but also the logistics information system as a whole is endangered and thus the emergence of the so-called bottleneck. About such functioning or malfunctioning LS are mentioned by the authors *M. STRAKA and M. BALOG* in their publications [1]. An important aspect of the logistics system is its construction. More detailed information on the possibilities, variations and construction of the logistics system can be found in the publication *of D. MALINDŽÁK* et al. entitled Design of the logistics system [2].

In the field of RFID technology, there has been a major shift in the last few years, as evidenced by publications from various foreign authors. *Mir-Moghtadaesi of Shahrekord University* describes the operation of the UHF frequency as a frequency that can reduce interference between RFID systems. He describes this study in a work entitled*: A newUHF / ultra-wideband radio frequency identification system to solve the coexistence issues of ultra-wideband radio frequency identification and other in bandnarrowband systems* [3]. The use of RFID technology requires a number of different components that are necessary for its effective operation. The authors *of Babaeian et al. from Monash University in Australia* created a study in which they describe the algorithm of operation of the reading device and detection of the RFID chip at a certain distance [4]. A study by *Occhiuzzi et al. from the University of Rome* talks about the use of simple RFID chips in food packaging. This study assumes an almost unlimited use of this technology in various industries and levels of the logistics process. The study, entitled: *Radio-Frequency-Identification-Based Intelligent Packaging: Electromagnetic Classification of Tropical Fruit Ripening* [5], was an inspiration in creating an article and understanding simple communication through RFID tags.

The issue of RFID technology is described in more detail in the publication *Analysis and Assessment of Management and Control of Component Flows for the Needs of Production in a Specific Company* [6]. This publication narrowly describes the development of RFID technology in Slovakia. It deals with various variations of technology and their use in everyday life. A more specific use of this technology is described in the publication *KOVALČÍK, J: Project of the use of automatic* *identification systems for the needs of management and control of material flows and identification of inventory in a specific company environment* [7]. The work is focused on the specific use of this technology in practice. Describes the positive and negative elements of the technology, points out the way of its use in the assembly and engineering industry.

## 2 Methodology

Company Alfa, which is the subject of the investigation, is a major market player in the engineering and assembly industry. The problem that necessarily concerns Alfa is the system of automatic identification of parts. In connection with the above, their goal is to create a smart logistics project. The project will deal primarily with the identification of parts in the production process, their registration in the production process and, last but not least, the improvement of the information system. . This analysis is carried out directly on the company's premises with the help of responsible employees in individual areas. The system approach and algorithmic thinking are applied in the analysis. The task is to create a project for the use of automatic identification systems, primarily for the needs of registration and management of parts in the production process. The project must take into account all the elements that could affect the proper and effective functioning of the system. In Alfa, it is mainly the diverse nature of individual types of parts [8]. The aim is to characterize the current situation in terms of information system and technical support for process monitoring in a particular company and to design a system that will use SAI. To effectively create a project, it is important to know the type, nature and functionality of each available technology that can be used in the issue [7]. Management and workers in production halls are fully aware that there are areas in warehouses and in the production process where monitoring of logistics processes is insufficient, but they cannot identify them correctly. Therefore, it is necessary to use analytical methods that determine the relationship between cause and effect and make it possible to determine the consequences. These relationships can be illustrated in various diagrams in a simple and clear way. Alfa's production process is too complex and lengthy, so it is not possible to start the planned project in all production halls at once. After a professional consultation at Alfa, we decided to shorten this production process [7].

It includes the monitoring of logistics processes [7]:

- stationary stations for deregistration of production,
- radio frequency scanners,
- forklifts,
- logistics train,
- trucks of internal transport,
- controlled intermediate storage of parts and input material.

The problem areas were analysed during my time at company Alfa. Individual problem areas were identified after professional consultation in the company [6]:

1. Failure to check out the realized operations in production orders in real time (often at the end of the shift), this makes it impossible to relocate work in progress when moving production to other halls (production of a work in several halls).
2. Due to overloading of production capacities and non-fulfilment of delivery dates of purchased materials, is not in accordance with the planned production dates, which are based on the required shipping dates of wagons or bogies according to the project schedule.
3. Materials (most often pallets of various sizes), which exceeds the current state of packaging in TVP. Subsequently, this problem is solved by storing several types of parts in one pallet and thus violates the rules for the smooth transfer of unfinished and finished parts in production and in warehouses.
4. Identification of the contents of the pallet by a loosely enclosed paper guide gives the presumption of its loss during transport, incorrect and incomplete filling by the operator, impossibility of transferring the change to the already existing guide, etc.

## 3 Current functioning of registration processes in the company Alfa

Production in the company Alfa can be characterized as custom variant production, in which the customer has a relatively high degree of freedom to determine the technical parameters of railway wagons. It can be divided into two basic groups: 1. Requirements for the supply of freight wagons and bogies 2. Small orders for the supply of spare parts or services. Both groups of customer requirements are realized by mutual agreement between the customer and the supplier, which in the first case is concluded by signing a business contract and, in the latter case, by placing an order with the customer. The first group of customer requirements, which in terms of time last several months, is realized through projects, the second group of requirements has a short implementation time, several days, weeks and it is realized by special production into stocks of specific sales orders - custom production [9]. in the company it represents an individual business case, with all phases of its life. The project at Alfa manages the part of production whose subject of performance towards the customer is the delivery of agreed numbers of entire railway freight wagons or separate bogies, with gradual dispatch, according to the agreed time diagram - dispatch plan. The production of wagons and chassis represents a significant majority of production, against the production and supply of spare parts for Alfa products, or small supplies of services, which use the free capacity of special technologies available to the company. Monitoring of the entire project life period in the pre-production and production stages is processed in Alfa, in the SAP information system using the Project System module [7]. The whole business case is divided according to the dispatch plan and production capacity possibilities into production batches, which according to the SAP system are referred to as SPP elements of the project (Structured project plan). The realization of production takes place from elementary parts, through the assembly of structural units of wagons and bogies, to the final assembly of wagons and bogies and the vast majority is project production, a certain minority part of the production of basic parts is realized by anonymous production to the warehouse. These are usually universal parts used in several projects, which are produced in economic batches [9].

### 3.1 Identification of production operations

The complexity of the final products (wagons and bogies) and the prevailing project batch production mean that thousands of production orders are realized in parallel in production, from the production of elementary parts, through orders for subassemblies and assemblies to final assembly: production of wagon and bogie superstructures. Each production order is currently identified in production by a paper guide, which contains all the information needed for production but also identifies the status of the production order with the marking of manufactured pieces for the operation and identification of quality control [10]. The production order guide contains the following basic information [11,12]:

- number of the manufactured component, • required production quantity,
- dates of order production (start, end),
- warehouse where the finished component is stored,
- production centre determining the subsequent consumption of the component,
- supply area production from which consumption is realized in a higher stage of production,
- link to the relevant T-element (if the production is anonymous link to T-bill is not defined),
- complete workflow with determination of time standard for individual operations
- material requirements tied to individual operation.

Work-in-progress production orders for parts are shifted in production, most often in pallets, large parts in bulk. During the life of the order, the transport pallet changes several times (depending on the complexity of the workflow, which includes discrete cutting and machining operations), but the guide moves with the work in progress. In the case of division of the order, when the production order proceeds to production in several transport batches, a new guide is printed for each batch. Each sublot of the production order must be identified by a guide [13]. In the SAP system, transport batches are defined for each part transported in pallets, specifying the type of pallet in which the part is to be moved in production (determined by the part size) and the transport batch quantity (determined by the load capacity of the selected pallet and part weight). After the end of the production of parts, these are stored in a central warehouse (WM warehouse) from where the parts are delivered on the basis of the requirements of the assembly workers in the area of supply of production in the assembly halls. In the case of time slips in the production of parts, these are delivered directly to the assembly lines [14].

At the central warehouse, the guide represents an identification element about the stored part, which contains information [15]:

- part number,
- quantity in the pallet,
- project SPP number,
- production warehouse (assembly line where the material is to be stored),
- production supply area on assembly line where the part is to be delivered.

The environment of production of parts corresponds to classical engineering production and therefore the paper form of identification of production orders about the content of parts in the pallet is not optimal, it is prone to damage and loss (Figure 1). The subject of optimization of logistics processes within this project is the process of controlled material flow of production of parts up to delivery to assembly lines and threads connected with it:

- ensuring the consumption of input materials for production orders with identification of the batch consumed in the operation,
- operations with assignment of quantity of good and bad pieces produced,
- identification of causes of deviations, identification of the person or working group who performed the operation,
- check-out of quality control operations,
- storage of parts in the warehouse unless automatic reception is set for reporting with the last operation,
- optimization of warehouse structure [7].

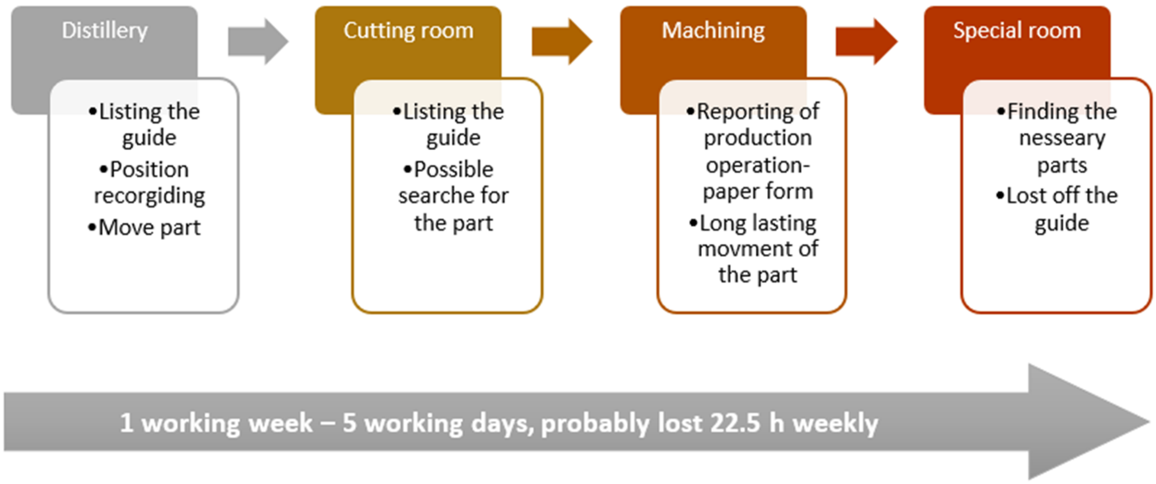


*Figure 1 Current operation of parts process monitoring [7]*

### *3.2 Summary of the analysis of the current state of operation of processes in the company*

The subject of the optimization of logistics processes in Alfa is the elimination of weak points in the current process monitoring, using modern technologies of data collection directly in the production process and in warehouses. It is necessary to optimize the process of monitoring the production of parts and their material flow, allocation of pallets and their content. A wide range of manufactured parts and a high degree of completion of production orders, which are realized in several production halls and are stored in multiple warehouses (controlled and unmanaged) requires quick availability of information on the current allocation of work in progress, identification of pallet number in which it is located and quantities. pieces in the appropriate pallet [16].

Within the project, the priority is to solve the following specific tasks [17-22]:

1. Monitoring the flow of work in progress over time - its exact position and degree of work in progress, quantity in packaging.
2. Automatic restocking of work and finished part during its transfer between export points or export point and intermediate storage.
3. Removal of the paper form of the guide as a basic identification element in the current functioning of the logistics process.
4. Removal of the paper form of the request for delivery of material to assembly lines.
5. Navigation of the import of material to a specific area of production supply.
6. Places in production with recording: production order numbers, operations, good pieces, bad pieces, the cause of the deviation and the personal number of the worker (or group of workers) who carried out the operation. If the input material has been used for the operation and is batched, it is necessary to record the number of the consumed batch.
7. Reporting the quality control operation and releasing blocked stocks in quality to free use.

## 4 Smart logistics project proposal

### *4.1 Pilot version of the project*

This project is to be a pilot version of the implementation of the automatic identification system in Alfa into the entire operation. At the moment, the project is commissioned only for a certain part of the material flow, due to the fact that for a wide range of production in the company Alfa, it is not possible to implement this project at once in all production halls and on all necessary parts. The project currently concerns four production halls, the visualization of which together with the parts will be presented in the following section. For the successful implementation of the project into the entire operation, the pilot version should be a kind of simulation of the behaviour of workers and production, to the system of automatic identification. As already mentioned, the project does not cover the whole operation, and the same applies to parts in production. Three types of parts were selected for the project, three types of their storage and three types of marking of these parts. The parts represent all possible storage variants in Alfa. Each tag / chip used for labelling must be rewritable (Table 1) [18].

| Pieces | Type of storage | Label type |
|---|---|---|
| Type A | On leave | Magnetic tag/chip |
| Type B | Ind corral pallets | Fixed tag/chip |
| Type C | Plastic crates | Adhesive tag/chip |

*Table 1 Types of parts, storage and type of marking [7]*

| Pieces | Type of storage | Label type |
|---|---|---|
| Type A | On leave | Magnetic tag/chip |
| Type B | Ind corral pallets | Fixed tag/chip |
| Type C | Plastic crates | Adhesive tag/chip |

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Alfa's requirements include both software and hardware requirements. In terms of logistics and focus, however, we will focus only on components of the hardware type, which are necessary for an effectively created project and also the correct operation of the material flow in the company Alfa (Figure 2). A high percentage of RFID components on the market are made to order. In the case of the smart logistics project and Alfa, which is the contracting authority, this is the same [19]. Custom components are compatible with a large number of software modules used to output technology, so there is no need for a more detailed analysis at this time. The project is currently in the phase of finding a supplier of these components, so there are no relevant outputs for it in the form of orders. However, for the needs of the research, there are similar components on the market that can be used [20].

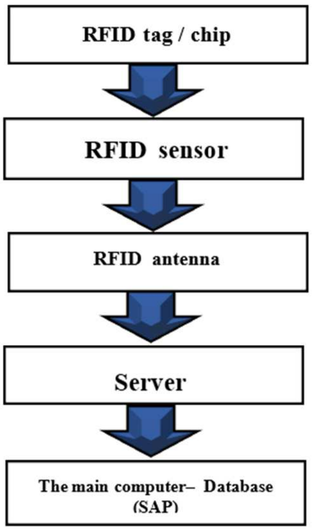


*Figure 2 Components needed [7]*

### *4.2 Number of required components and visualization of components in production halls*

When visualizing the halls (Figure 3, Figure 4), it is necessary to take into account the area in $m^2$, each of the stationary sensors and mobile sensors has a maximum scanning distance. In the case of mobile sensors, this problem of logical range is logically eliminated; an adequate number of such sensors will be allocated to the halls after consultation with Alfa, due to the size. However, stationary sensors require efficient placement in production halls. In table no. 2 we process the individual halls and find out how many stationary sensors we have to use to cover the whole space (Table 2).

The same principle applies to RFID antennas, as the antenna we choose will collect and send data from both stationary readers and mobile ones. The selected stationary sensor has a maximum range of 25 m perpendicular to the object. The signal from this sensor can be defined as a circle, where the centre is a stationary sensor, and the radius reach perpendicular to the object. In our case, it is necessary to calculate the content (1) of this circle. A simple equation for calculating the content of the circle suggests that one stationary sensor covers about 1970 $m^2$.

$$S = \pi \times r^2 \tag{1}$$

*Table 2 Number of required components [7]*

| Hall | Process | Area in $m^2$ | Number of components | | |
|---|---|---|---|---|---|
| | | | Sensor | | Antenna |
| | | | Moving (pcs) | Stationary (pcs) | |
| Hall n.1 | Distillery | 4 532.22 | 7 | 3 | 2 |
| Hall n.2 | Cutting room | 2 649.45 | 4 | 2 | 1 |
| Hall n.3 | Machining | 6 345.84 | 8 | 4 | 2 |
| Hall n.4 | Special room | 11 371.62 | 10 | 6 | 4 |

## 5 Results and discussion

During the analysis of the current functioning of logistics processes in the company Alfa, it was found that the current system primarily prolongs the production time of the complete building. Whether it is a complete railway wagon, bogie, resp. another necessary part of the product. In a manufacturing company and especially in logistics, the individual processes are consecutive, and therefore the time of production of a particular object is closely related to finance. It is therefore necessary to convert the time lost in the current system into financial form. In this work, we focused mainly on the parts called A, B and C. When calculating the return on investment, it is currently pointless to define a specific part [7].

If we define a working week for 2 changes, after 7.5 hours, 5 days, then we will get the working time. **75 hours per week.** After the analysis in the company, it was found that the time that employees lose when writing a guide, unnecessary relocation of parts, respectively. parts search accounts for about 30% of that time. This figure represents exactly **22.5 hours per week and 90 hours per month**. As mentioned, time is closely related to finances, so it is necessary to convert the figure of 90 hours per month using the so-called "Man-hours" for finance. According to an available calculator from the Ministry of Labour, Social Affairs and Family, 1 "man-hour" represents several **16.80 € per hour**. This fact, after a simple mathematical operation, determines the amount of **1.512 €** per month, which represents a loss caused by unnecessary manipulation of parts, irresponsibility and inconsistent material flow.

After the implementation of the smart logistics project, this amount and especially the time should be significantly reduced. During the consultation of the project at Alfa, it was found that the implementation of the project had a figure **of 22.5 hours per week and thus 90 hours per month reduced by several 75%.** This fact represents an investigation **of 17 hours per week and thus 68 hours per month. From a financial point of view, this represents a final amount of 1,142.4 €** (Figure 5, Table 3).

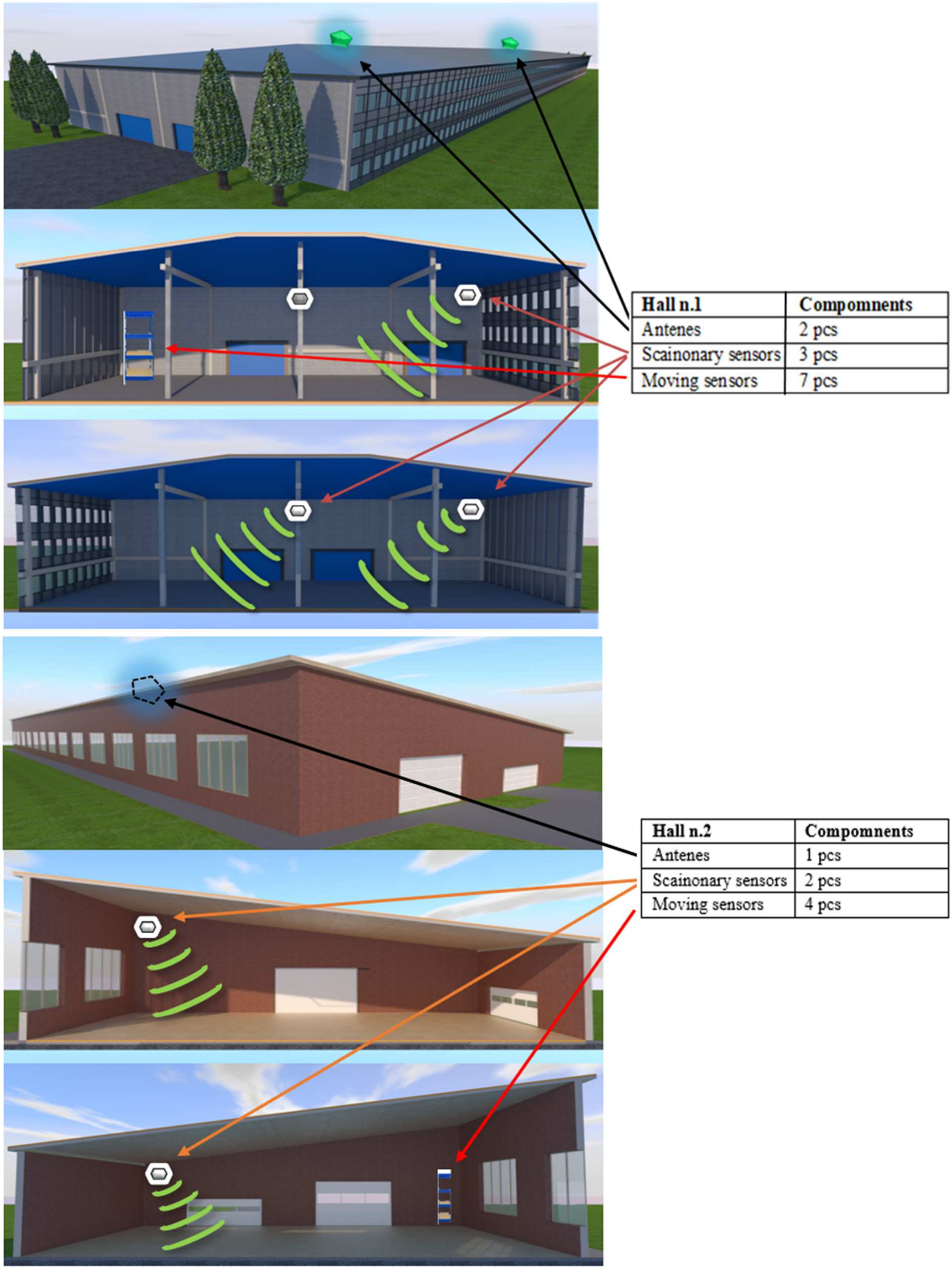


*Figure 3 Hall n.1 and n.2 components [7]*

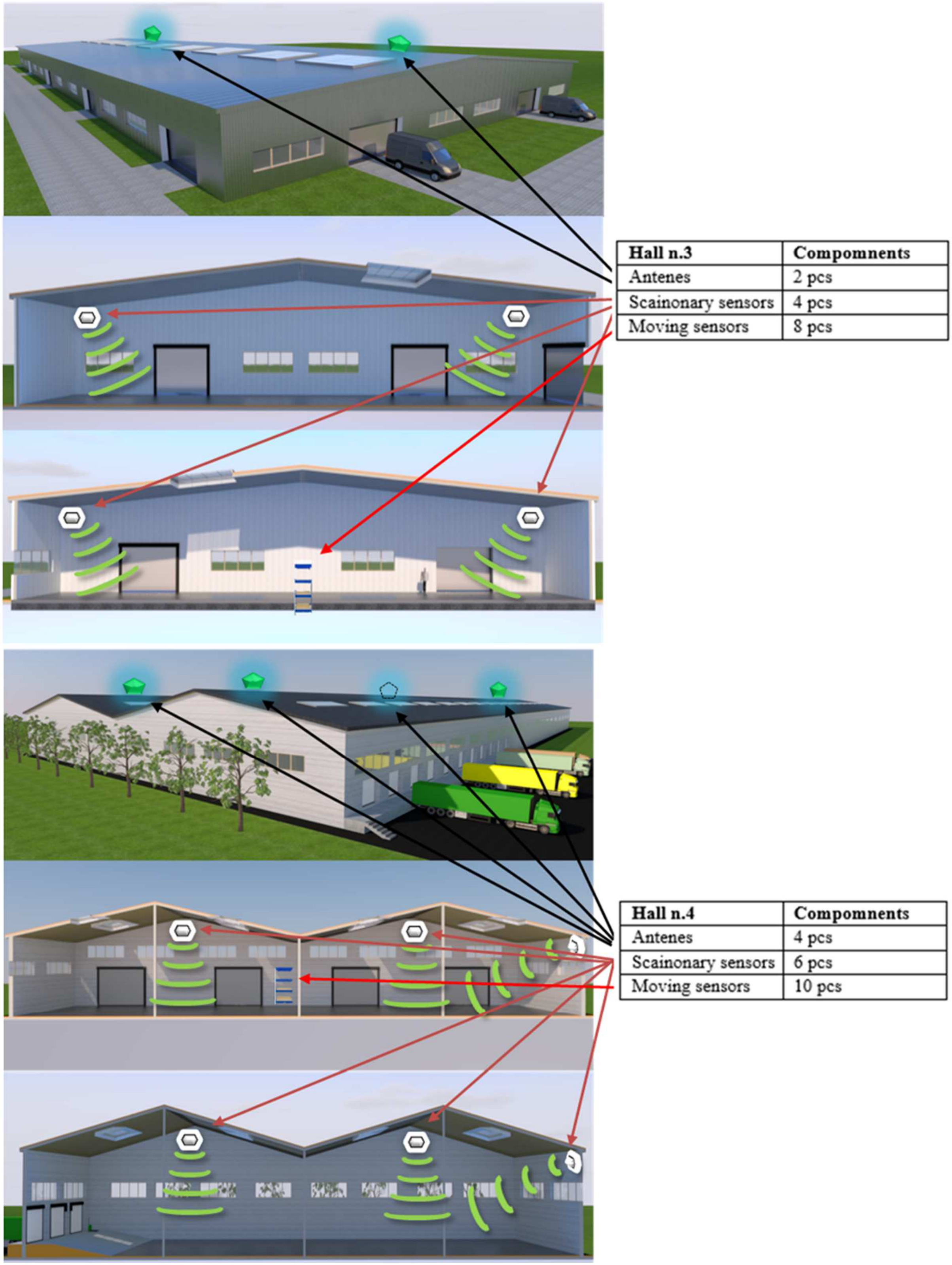


*Figure 4 Hall n.3 and n.4 components [7]*

The data from the economic enumeration [7] tell us that the investment in the pilot project is **58,425 €**, and thus the return on investment for the pilot part of the project is € 58,425 / € 1142.4. In our case, the investment in the project should return within some 52 months, which represents **4 years and 3 months.**

Even after the implementation of the project, the company will not avoid certain financial losses. However, these are related to the operation of RFID technology. This amount is € 1512 - € 1142.4, which gives us the amount of € 369.6 per month. It is obvious that the implementation of the project will achieve a significant monthly decrease in the number.

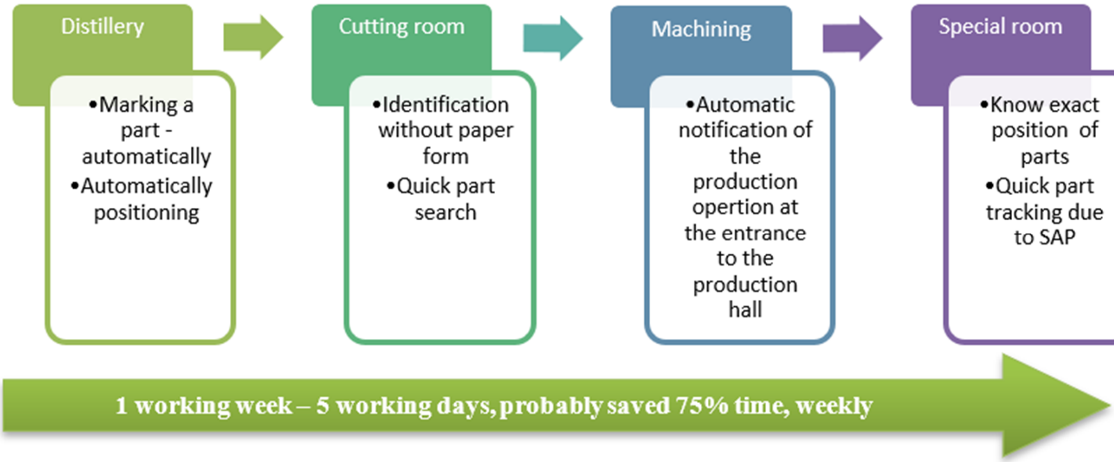


*Figure 5 Scheme of operation of logistics processes - SMART logistics [7]*

*Table 3 Results of the project*

| ---------- ----- | Curent function | - | ----------- ---- | New function |
|---|---|---|---|---|
| Working week / month | 300 h | - | Working week / month | 300 h |
| Lost time in %/ month | 30% | - | Save time in % / month (from 30%) | 75% |
| Lost time in hours/ month | 90 h | - | Save time in hours / month | 68 h |
| Lost money / month | **1512 €** | - | Save money / month | **1142.4 €** |

## 6 Conclusion

Automatic identification systems are among the models with high implementation costs. This is mainly due to the need to incorporate many timeless elements into Alfa's system. However, its advantages outweigh any existing solutions for the material flow control and inventory identification system. As mentioned, implementation requires many elements. For the pilot version only, the cost of implantation can climb to large amounts. The pilot version of the project requires the purchase of tags / chips, sensors, antennas, servers, the main computer, cabling and, last but not least, assembly. In addition to the mentioned elements, there are also items related to the storage of parts. Of course, the company has a number of such elements, but it is up to the company to consider whether its investment will concern the purchase of new, respectively. keeping old handling units. The loyalty of the company's employees is also a very important fact in the implementation of the project. The core of this project is automatic identification, but even with this fact it is not possible to completely remove the human factor. The nature of production does not allow it. A larger percentage of sensors in the pilot version of the project is of the mobile type. This fact will logically require quality training of staff.

The implementation of the smart logistics project should be a part of the entire operation in Alfa after successful testing. Its benefits will be felt after only a few production cycles. From the point of view of logistics, the project will significantly help to monitor the material flows of work in progress over time. Thanks to tags / chips, which are rewritable and have a relatively high memory, it is possible to monitor the exact position, degree of work in progress, resp. the number of pieces in the package for the parts in question. The use of SAI can be understood in the Slovak market as an innovative use of modern technology. With the help of this project, it is possible to get rid of an obsolete identification element in the logistics process. The paper form of the guide is a problem nowadays. Especially if it is such a lengthy and demanding production as production at Alfa. Assumption of loss, resp. damage is very high. It is this fact that company Alfa paid significantly for. **If we define logistics as a way, a philosophy of management, including material flows, then the loss or damage to a single identifier in the production process is a significant problem for the further continuation of the material flow. We are talking mainly about the planning of production capacities or production dates**. This situation logically results in non-compliance with export deadlines, which results in a damaged reputation of the company. By implementing the project, we can achieve significant progress in the field of logistics, inventory monitoring and material flow. The nature of production in the company is extremely complex. However, it is appropriate that the company is constantly introducing various elements to accelerate and innovate it. Therefore, the question is whether the company does not want to focus on complete automation of production in the future. I believe that a major player in the market, such as Alfa, can make a big difference.

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# THE IMPACT OF LOGISTICS ON THE COST OF PREFABRICATED CONSTRUCTION

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***Keywords:*** logistics planning, prefabricated construction, wood-based buildings, transport cost, storage
***Abstract:*** The aim of the paper is to emphasize the need for logistics planning in prefabricated construction in Slovakia. A construction contractor can achieve profit and efficiency of a construction project through well-managed resource logistics. Moreover, it helps to ensure the competitiveness of prefabricated construction compared to traditional on-site construction. In the case study of a wood-based family house, the construction cost and the transport cost are analysed in relation to available logistics chains. Three variants of wood-based construction systems are adopted in the study: the column-beam construction system, the construction system based on Structural Insulated Panels (SIPs) and the panel construction system. The results of the study found that the transport cost does not represent a large share of the total construction cost of the wood-based family house. This applies to all three variants of the construction system. A well-planned logistics of resources – people, materials, machines – can help to achieve an efficient and rational construction cost and construction time of a project. Thus, a client of a wood-based prefabricated building does not have to worry that the transport cost related to the transport of large, prefabricated components will make the construction of the building markedly more expensive.

## 1 Introduction

Currently, a continuous improvement of production efficiency is emphasized in construction. A proper type of construction material logistics and prefabricated components logistics in off-site construction can significantly contribute to enhance construction efficiency [1]. On the contrary, an inaccurately managed logistics may significantly increase construction cost. To remain competitive in the construction market, some manufacturers of prefabricated components for off-site construction, provide services only to a delimited distance from their factories. Otherwise, the logistics cost will increase to such an extent that the cost of a construction project will be significantly increased. Such a construction project accounts for a certain point of inefficiency and inefficient cost spending. In the long term, this can be reversed only if other monitored parameters of the construction project can guarantee economy and efficiency [2,3]. These parameters are such as for example use of prefabricated building components with a reduced carbon footprint in production, components with a reduced ability to emit pollutants into environment, components with a reduced overall environmental impact of production, etc. [4,5]. To ensure sustainability in construction, these parameters should be followed [6,7]. The life cycle environmental impact of prefabricated wood-based constructions can be assessed by the software Athena [8]. The off-site construction ranges manufacture and assembly of prefabricated components on various material bases such as wood, concrete, steel and their combinations. From logistics point of view, the planning of a nice flow of resources needs to be carried out for both framework construction products and finishing construction products (e.g., for prefabricated building façade systems) in all construction segments [9]. In order to be effective, the construction logistics could largely follow the example of other industries. The production of building components for direct assembly into a building is a characteristic feature of prefabrication. This develops the possibility of Just-in-time construction without need to store prefabricated construction products at the manufacturer and it also eliminates the storage of products in various intermediate warehouses within the supply chain. Over the last half century, many manufacturers in off-site construction have sought to achieve the "Zero Inventory (ZI)" production. The logistics processes are also affected by the Fourth industrial revolution. In particular, it concerns the automation of storage in order to facilitate storing and dispatching operations. The Zero-Warehousing Smart Manufacturing (ZWSM) production platform was developed in Hong Kong. This concerns the principle of avoiding traditional storage operations and reducing storage spaces to a minimum. The platform is based on the use of synchronization, unitization and the Internet of

Things (IoT) enabled infrastructures. The authors of the ZWSM applied the platform to a case study of a prefabricated construction project in Hong Kong, in which they pointed out the success of zero storage of prefabricated elements [10,11].

Loss of productivity through delays and interruptions of works on site is one from significant problems in the construction. This can be caused by collisions in workforce, material and machinery. Improvement of construction logistics efficiency, concerning the flow of material and products from factories to the place of installation on a construction site, is one from the central needs of the construction industry. To examine the efficiency of integrated construction supply chain logistics, a research study has been conducted in the United Kingdom [11]. The 4D Building Information Models (BIMs) were applied in the research. As the research results demonstrated, the 4D BIMs are not yet widely used in practice to plan and monitor supply chains during construction.

The flow of material to a construction site is characterized by two types of construction supplies. It is a supply of common piece materials and a supply of prefabricated components. The cost of delivery of building material in both on-site and off-site construction methods can be optimized with the help of appropriate logistics planning. In both types of construction, the plan of

a logistics system for efficient construction processes seems to be a problem. It is necessary to solve tasks with timely delivery and storage of material. The aim is to optimize the efficient use of resources and to reduce traffic related to construction tasks to a minimum. The adoption of CCC – Construction Consolidation Centre (Figure 1) is one of ways to achieve this goal [12].

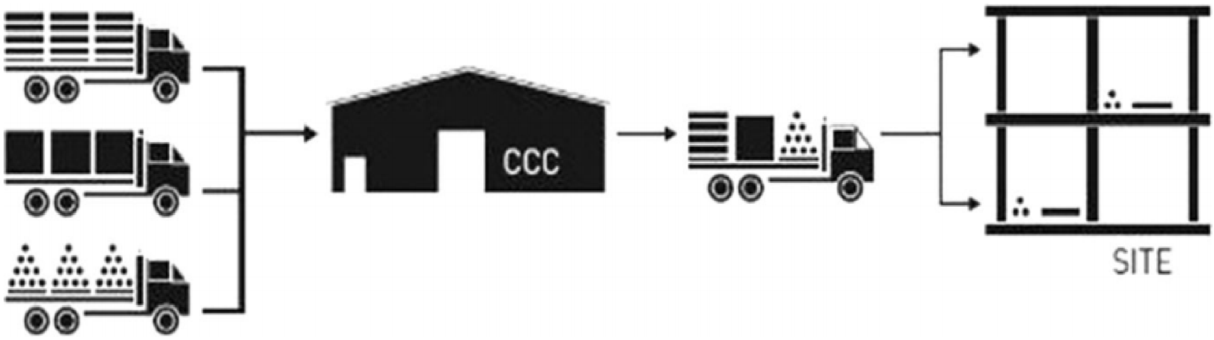


*Figure 1 Principles of a construction consolidation center (CCC), adapted from Lundesjo (2015) [12]*

The Construction Consolidation Centre (CCC) is a distribution facility that can be used in the process of managing project logistics, channelling material deliveries to a large, single construction site or to several different construction sites (Figure). It facilitates the efficient flow of materials through the supply chain, reduces waste and other problems such as goods flow congestion. Building materials are delivered from suppliers to CCC where they are stored until the delivery to the construction site is required [12].

To understand the importance of logistics in construction projects, the concept of the logistics in construction should be accordingly defined. The logistics is defined as planning, execution and control of the procurement, transport and placement of material, human and other resources to achieve the objectives of a construction project. The transfer of prefabricated components from the manufacturing plant to the construction site is a simple illustration of logistics for construction sites supply. When prefabricated panels are delivered to assembly site, a lifting equipment will be needed to install the prefabricated components directly from the vehicle, i.e., cantilevered construction. Prefabricated panels represent the material, a lifting crane is the equipment and there is also a crew of workers who will assemble the panels. The logistics allows getting all three components of resources to the same place at the same time. Moreover, the logistics has a significant impact on profitability. If the crane is not in the place when it is to be, the crews cannot start assembly works. They receive their hourly wage despite the fact the crane is not ready for assembly and assembly cannot begin [13]. In addition, as far as construction process, the delay of one activity makes it impossible to start the next one. Thus, the construction readiness for the following crews will not be maintained. If execution of some critical path activity (CPM – Critical Path Method) is delayed along of poor logistics and wrong organization (Figure 2), the construction time of the whole project will be extended [14].

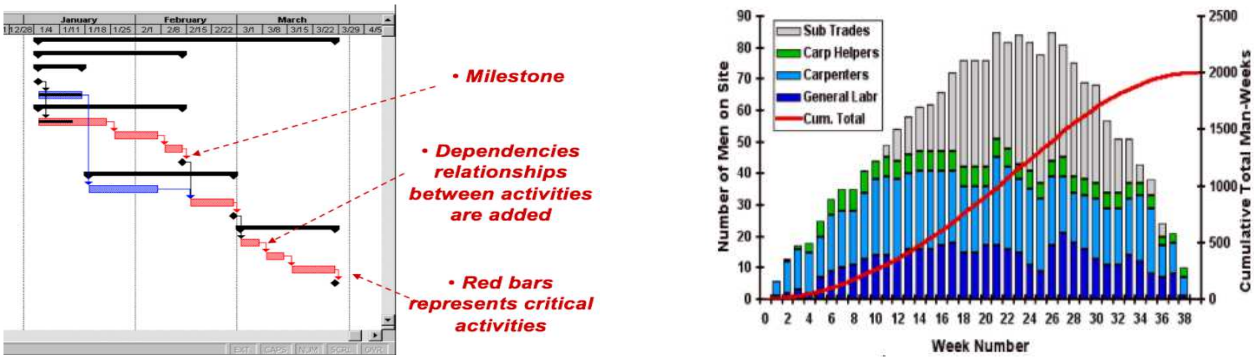


*Figure 2 CPM [14] and Histogram of human resources and S-curve [15]*

If prefabricated panels are installed late, the following professions can also be delayed, for example, partitions assembly, electrical installations, air conditioning, installation of floors and other trades. In the preliminary phase of a construction project, the general contractor must make a construction schedule for each stage of the project. The time plan must contain an overall list of materials, equipment and tools needed for each stage of the project. This involves planning the flow of resources with the help of histograms of workers, equipment, and materials (Figure 2). Advance planning helps ensure the right materials are in place every day so that construction teams can work without any interruption. Logistic planning also means that materials are stored in adequate quantities, are easy to locate and easy to handle.

## 2 Methodology

A carefully planned logistics of production resources can ensure the efficiency and economy of construction process. The presented study deals with the construction of wood-based family house. The impact of transport cost on the total construction cost is examined. The transport cost is one of the factors that must never be neglected in issues of optimization of construction from prefabricated components. Many off-site construction companies don't provide their services to long distances from their factories. The reason usually lies in the failure to manage the logistics of the project. On account the lack of right logistics, excessively high transport cost in relation to transport of prefabricated components from factory to construction site are calculated.

### *2.1 The transport of wood-based prefabricated components*

In off-site construction, the transport of prefabricated components is an important loop between the components manufacturing in factory and assembly on construction site. The transport involves i) off-site transport – shifting from factory to site and ii) on-site transport – shifting within construction site area. The off-site transport is represented by horizontal transport to longer distances. Components are by goods vehicles shifted from a factory to storage area on construction site or to some assembly equipment (in case of cantilevered construction). Even if, the railway transport is applied in the construction sector, the transport of components for wood-based prefabricated construction projects is mostly realized by means of vehicles. The transport of components within area of construction site can be horizontal or vertical to short distances; several types of vehicles and cranes are applied. Prefabricated components are stacked on a vehicle with respect to a construction schedule. The installation sequence should be taken into account. The plan should ensure a right layout of the components on the vehicle for the purpose of well-organized successive taking of material during assembly without placing it in the storage place. Both types of transport can be used to transport different types of prefabricated components. The prefabricated products involve beams, flat walls and modular components. It is important to plan a reasonable logistical flow of all the resources – material, equipment, and human – for a whole off-site construction project.

The case study involves three different construction systems of wood-based buildings: i.) the panel construction system ii) the column-beam construction system, and iii) the system of "Structural Insulated Panels (SIPs)". The construction cost (involving cost of labour and material), the equipment rental cost and the transport cost with regard to the specific available logistics chains were estimated for the three mentioned variants of construction system of a wood-based family house.

The model building of the wood-based family house in Pezinok, which is located about 17 km from Bratislava, was applied in the case study.

### *2.2 The types of analysed construction systems*

The panel construction system of the family house is characterized by large-scale panels, manufactured in a factory and assembled on a building site. The panels are delivered to construction site in the third stage of prefabrication – with windows installed (Figure 3).

*Figure 3 The panel construction system*

The column-beam construction system is characterized by framed light-weight construction from structural timber elements (Figure 4). The principle of the construction system was taken from America and Canada, and nowadays, it is the most widespread construction system of wood-based family houses in Canada.

*Figure 4 The column-beam construction system*

The construction system based on Structural Insulated Panels (SIPs) is characterized by modern sandwich construction (Figure 5), the core of which consists of hardened polystyrene and is clad with oriented strand boards (OSB). Unlike classic wood-based buildings, the cross-section of the construction doesn't contain a wooden frame.

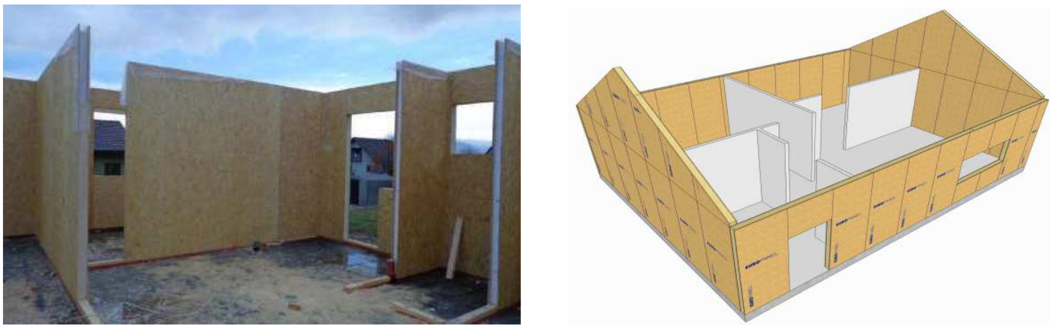

*Figure 5 The construction system of Structural Insulated Panels (SIPs)*

### 2.3 The transport distances in the case study

To estimate the transport cost of the wood-based construction in the three mentioned variants of the construction system, the model case of the family house in Pezinok was seen about. The town of Pezinok is located about 17 km from Bratislava (BA), the capital of Slovakia. To determine the transport cost, the transport of the components from the city of Bratislava to the town of Pezinok was considered. The following list of suppliers of construction material for the studied construction systems introduces the distances from factories or from warehouses to construction site in Pezinok:

- supplier of the structural timber: Sawmill Holz transport BA – the transport distance 22 km,
- construction material: Building materials Woodcote BA – the transport distance 17 km,
- trussed tie-beams: Dachteam BA – the transport distance 17 km,
- gypsum fibre boards: Baustoffmetal – the transport distance 19 km,
- windows: Incon BA – the transport distance 22 km,
- Structural insulated panels: Europanel BA – the transport distance 22 km.

### 2.4 The estimation of construction costs of the model wood-based building

The construction costs were estimated with the help of software Cenkros4. It is the most used construction cost estimating software in Slovakia. It enables efficient processing of price offers with current prices of building materials and construction works. The software uses the database of building materials, which is processed by Cenekon as the largest supplier of price list databases in Slovakia. The construction costs were calculated on the basis of design documents of the three construction systems of wood-based buildings.

## 3 Result and discussion

We can say that siting of the presented family house in Pezinok is strategically advantageous in terms of logistics of construction resources. In the vicinity of the capital, it is possible to provide a logistics network of resources at much good level. If delivery of some source fails during the construction process, it is possible to replace it with another source, without increasing cost and wasting time. In other places of the country, such an alternative replacement of resources could be considered as a logistical problem which can result in a significant increase in cost and in extension of construction time. Especially, when it is concerned the construction operations from the critical path in the CPM plan.

The transport of the wooden panels in the variant of the panel construction system is carried out by means of trucks. The layout of different pieces of perimeter and partition panels on the truck is in suit with the assembly order of the family house. The perimeter and partition panels and trussed tie-beams are transported in a vertical position, i.e., in the position in which they are to be installed in the house. If horizontal components, such as floors and finished roof parts, should also be used, the same logic would apply. Thus, the components should be lying in a horizontal position and in the order of assembly. In the case of this construction system, the storage of components in the construction site is not necessary, as all the components are unloaded by crane directly from the truck and are assembled into the building.

The transport of the components in the case of the column-beam construction system is carried out by the flatbed vehicles with a mechanical arm. The timber elements should lie on three base prisms, in a horizontal position. The timber elements and other elements of the column-beam construction system must be protected from the weather by covering with a tarpaulin. The Fermacell gypsum fibre boards and Isover insulation boards should be placed under the roof inside the building, in order to protect them against possible moisture.

There are a few simple rules for transporting the components for the building based on the SIPs. The rules are important to follow. The panels must always be transported and stored horizontally. Unloading on the construction site can be done by hands, as the heaviest panel weight is about 80 kg. When shifting by hands, it is important not to pull the top OSB of the SIPs. When storing, it is necessary to place the panels on three thin plates (it the beginning, in the centre and at the end), so that the panel is in a horizontal position. The panels can be stacked on the top of each other and the maximum load on the bottom panel is 1500 kg. The panels and other components of the building based on SIPs must be protected from the weather.

One of deficiencies in transport, storage and assembly of the family house lies in the fact that in all three variants of the construction system, the prefabricated components are not provided with Radio Frequency Identification (RFID) tags. From logistics point of view, the tags would simplify the identification of the components in the overall construction. Several research studies suggest that construction is one from the least digitized industries [16,17]. Recently published academic research and industry reports in the fields of Industry 4.0 and smart manufacturing of various components are also examined to provide detailed information on the current implementation of Industry 4.0 principles in various sectors of the economy [18]. In the presented case study of the family house, the costs related to transport of the prefabricated components to the construction site are calculated individually in the different construction systems of wood-based building. Based on the calculations, the resulting values of the costs are presented in the following graphs (Figure 6).

In available price-list databases of construction materials, the transport cost is involved in the unit price of each construction material if transport distance from a warehouse to a construction site is no more than 50 kilometres. Thus, the transport cost is included in the item "Material" provided that the transport distance is up to 50 kilometres (Figure 6). In case of prefabricated components that are not covered in the databases, the transport cost must be calculated individually in accordance with the distance from a factory to a construction site. The individual transport costs are presented by the item "Material Transport". Following the carrying companies, the calculation of individual transport costs involves a flat rate and the tariff rate depending on the number of kilometres from a warehouse to a construction site. In all three variants of the construction system, the construction cost of the family house is comparable. The construction cost of the wood-based family house is as follows: i) 33 568.92 EUR in the panel construction system, ii) 31 505.54 EUR in the column-beam construction system and iii) 34 379.87 EUR in the construction system based on SIPs. The highest transport cost – 1.30% of the total construction cost - was found in the variant of the column-beam construction system. In the study, the SIPs based construction system is characterized by the medium-large transport cost – 1.04% of the total construction cost. In the variant of the panel construction system, the transport cost is only 0.13% of the total construction cost. Such a low value of the transport cost was achieved mainly due to small distance from the production plant of prefabricated wooden panels to the construction site in Pezinok.

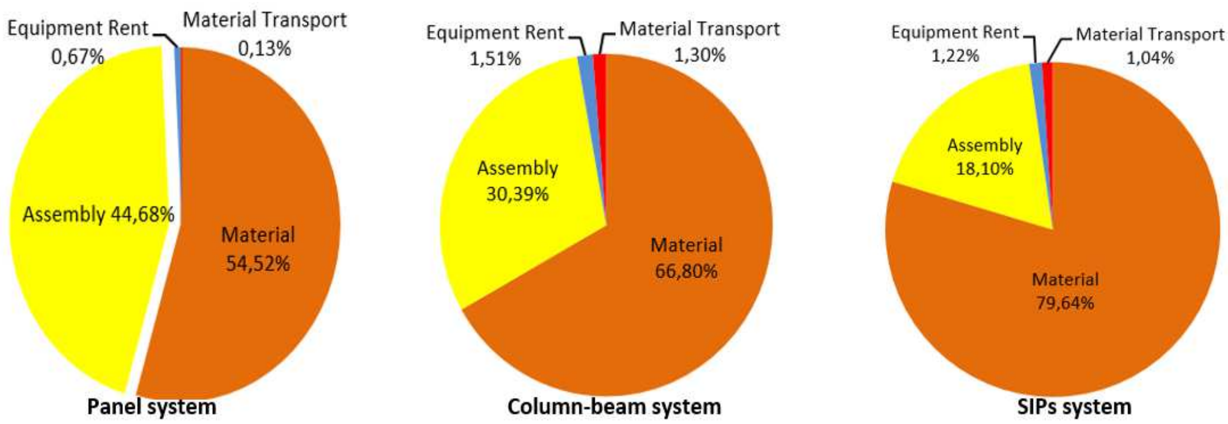


*Figure 6 The cost of the material transport within total construction cost in three variants of the construction system (from the left): the panel construction system, the column-beam construction system, the SIPs system*

## 4 Conclusions

When choosing the material base of a building, the investor makes decisions in accordance with the purchase cost. In marketing presentations of wood-based constructions, a reduction in the construction cost is initially expected, compared to a masonry construction system. However, in practice, the higher cost of wood-based buildings compared to masonry structures, is often proven. The prefabricated components make a higher cost of the wood-based construction system compared to a masonry construction system. The higher price of prefabricated houses is compensated by higher construction quality, higher accuracy in details and especially by better speed of construction. To ensure efficiency, economy and competitiveness, the contractors in off-site construction must make a precise plan of the logistic flows of construction resources, such as material, workforce and equipment. The contractors of prefabricated wooden buildings must count on the overhead costs associated with the production of prefabricated components, the operation of production plant with equipment, more demanding transport and assembly equipment and the overall logistics plan so that all resources are in the right place at the right time. The transport cost and the transport and storage methods of three presented variants of wood-based constructions – i.) the panel construction system, ii.) the column-beam construction system, and iii.) the construction system based on SIPs - are analysed in the paper. Managing logistics issues before and during construction will ensure that critical processes are completed at the right time and thus, the delivery dates are honoured. The analysis and the proposal of a methodology for the use of existing Advanced Planning & Scheduling (APS) methods to optimise and to improve the production and logistics planning in the segment of prefabricated buildings in Slovakia will be the subjects of the further research.

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# ANALYSIS OF INTERNAL LOGISTIC COST ON EXPORTS OF PERUVIAN COFFEE IN THE PERIOD 2015 – 2019

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***Keywords:*** logistics costs, transport, cluster, security, corridors
***Abstract:*** The objective of the research was to analyse the main components of internal logistics costs that are shown in the process of Peruvian coffee exports in the period 2015-2019. This study used various government sources, document review, and extraction of information systems. To do this we take into account 6 departments with greater coffee production, connected with three logistics corridors that have as a starting point the production areas and reach the export channels of Callao and Paita. Also, using the information gathered from the logistics performance index, a brief internal transport comparison was made between Peru and Colombia. As a result, the logistic cost of both countries is higher than 14.1% (Latin American average), taking into account that in both countries the only internal logistic component in which they coincide is transportation. It is concluded that national transportation hurts impact on logistics costs, since these are affected in the final price of coffee and the profitability of the Peruvian farmer.

## 1 Introduction

Currently, transport logistics is one of the fundamental pillars within the exporting companies, it has a great impact on the world economy, and is one of the indicators that have the greatest influence on the price of goods and services offered in national and international markets. Another important aspect to be assessed is the efficient organization of distribution and transport of goods since it plays a key role in the integration and coordination of logistics factors [1].

Inside agro-industrial exports, coffee is the leading product in Peru and globally ranks ninth behind Brazil and Colombia [2]. Peru is the eighth largest coffee producer in the world and the quality of its product is increasingly recognized in the international market due to its great organoleptic properties [3]. Since 2008, coffee has been considered a flagship product because of its value in the agro-export basket and because it influenced the economy of rural families, considering that the total number of farmers engaged in the cultivation makes up 95% and are small producers. 91% of the cultivated hectares of coffee, are accentuated in 6 departments. The total production of coffee within the country covers 19 regions, 63 provinces and 449 districts [2].

Because the coffee production plants are far from the city, a logistic transport system is created for the proper distribution of the merchandise. The main component of the total cost of Peruvian agro-industrial companies is logistics costs, ranging from 20% to 50% of the total cost, with coffee being the most efficient product in its logistics costs with 21.2% [4]. There are three coffee corridors: the Tocache-Zarumilla corridor, which connects the northern cluster formed by Amazonas, Cajamarca and San Martín (55.6% of total production) with the port of Paita; and the Satipo-Callao and Cusco-Callao corridors, which connect Junín (27.5% of total production) and Cusco (16.8% of total production) with the port of the capital, respectively. The production is transported to the collection centres in these same departments, or it is collected by intermediaries (collectors) who sell the product to processors, traders or exporters. Finally, the coffee is destined for the foreign market through the ports of Callao and Paita [5].

## 2 Literature review

### 2.1 *Internal transport*

According to P. Dorta [6], road freight transport is a key part of the logistics chain, mainly in the supply and distribution processes, but transport is closely related in the production processes, that is why it depends on the logistics chain.

The transport system includes the management of means, modes, loading, unloading and terminal infrastructure [7]. Also, safety, speed and regularity are indicators that help measure the performance of the transport system. The means of transport must have the necessary infrastructure in the roads, ports and airports, and must be modernized according to the needs and changes of the country.

According to J. Rojas [8] in his research article, he stated that the purpose of the transport sector is to deliver the cargo at the agreed destination, in a timely manner and preserving the integrity of the merchandise and how this is carried out raises a supply chain management system of land transport companies that can reverse internal transport non-conformities. Where I come to the conclusion that the figures for loss of merchandise and untimely deliveries reflect that an investigation is necessary to investigate the relationship of these events with the management systems.

According to F. Huamán & X. Puente [9], the objective of their research is to identify the relationship that exists between the costs and export competitiveness of blueberry exporting companies in 2016. The descriptive-correlational methodology was used where the different elements that influence this variable and appropriate strategies were applied to obtain great benefits to exporters, where the result was that there is a relationship between local transport and export competitiveness.

### 2.2 *Logistics costs*

Within the logistics field, logistics costs are related to the functions of a company that allows managing and controlling the flow of materials and information.

In addition, logistics costs are a fundamental part of logistics operations, where these costs are reflected in the movement of the product, from the warehouse to the port of departure of a country, the costs in which the merchandise consumes time, and the costs that they generate the logistics operations within the distribution process, whether from one origin to one destination, from one destination to many and from many to many [10].

The logistics costs include traffic and means of transport, storage, transfer of materials, supply, packaging and distribution [11].

According to M, Bossio; E. Cotillo & M. Delgado [12] carried out an investigation in which he described and analysed the different costs that encompass the international logistics activities that may arise at the time of developing an export, the topics discussed are based on the research of supplier's logistics service and specifications that must be met in each of the related entities to develop the export. It was concluded that the costs of the activities involved in the international logistics of an export product influence business management.

According to J. Luyo & V. Quispe [13] in his research work, he aimed to demonstrate the economic impact caused by the logistical costs on supply chain management in companies in the cosmetics sector. Where the mixed research method was used in which processes were identified tasks involved in supply chain management. it was concluded that logistics costs will have a positive impact on supply chain management in companies.

### 2.3 *External transport*

International transport is an important element in international trade logistics and should be used to get merchandise to the country of destination [14].

External transport implies the use of different means to carry out the mobility of the merchandise, where there are two modes of transport such as multimodal and intermodal. External transport in its entirety has always been intermodal, since goods have moved from their origin to their destination by changing the mode of transport, depending on the technology available at the time [15].

According to D. Ballestero [16] the external transport is made up of appropriate means of transport according to the type of load (liquids, gas, bulk materials, and unit loads), likewise, they include activities such as unitarization of the loads, palletization, unloading, and arrival at the destination port where there is a formalized system for planning and controlling the operation of the external transport system that guarantees the maximum use of the resources and a high level of service in the distribution and delivery of the products to the consumer. The physical and environmental conditions of the handling tasks, as well as those of load transport, guarantee adequate conservation of these and safe work with high protection for workers and operators.

According to F. Colque [17], the objective of the research was to determine the effect of international freight transport by road on economic competitiveness based on optimal cost-efficiency criteria. The inductive-descriptive methodology was used, wherefrom the particular diagnosis of two central variables: economic competitiveness and international transport, it was possible to identify those adverse factors so that in this way the problem environment can be defined with greater precision. In summary, international road freight transport had positive effects on economic competitiveness based on cost-efficiency criteria.

## 3 Methodology

The method used in this research is analytic-descriptive, where we designed a field study based on the documentary review of the 6 departments with the highest participation in the coffee production in Peru, corresponding to the period 2015-2019.

According to [2], in Peru there are 19 regions that grow coffee, however, only 6 of these covers 91% of the total production, consisting of: San Martin (22.2%), Junín (27.5%), Cajamarca (20.9%), Cusco and Puno (16.8%), and Amazonas (12.5%). There are three coffee corridors in Peru:

- The corridor Tocache-Zarumilla, which is connected by the cluster North, formed by San Martin, Amazonas, and Cajamarca, and count for 55.5% of the national production of Coffee.
- The Satipo-Callao corridor, which connects to the Junín cluster, where the largest source of production is located in the provinces of Satipo and Chanchamayo, with 17.1% and 10.4% of coffee production, respectively.
- The Cusco-Callao corridor, connected to the Cusco cluster, where production is mainly centred in La Convención, which is the second most relevant coffee province in Peru with approximately 14% of national production [5].

*Table 1 Participation of the top 5 coffee exporting companies*

| Cluster | Departments | Corporate name | % Part. |
|---|---|---|---|
| North | Amazonas | Café Monteverde | 24.825% |
| | | Cooperativa agraria Rodriguez de Mendoza | 20.34% |
| | | Cooperativa agraria ecológica cafetalera de Lonya Grande | 19.36% |
| | | Café El Bosque S.R. L | 9.53% |
| | | Cooperativa agraria Juan Marco el Palto | 7.26% |
| | San Martin | Cooperativa agraria cafetalera Alto Mayo | 46.00% |
| | | Comercio Amazonia SA | 18.85% |
| | | Comercio & CIA S. A | 11.30% |
| | | Asociación agroexportadora de la región San Martín | 8.06% |
| | | Cooperativa de servicios múltiples bosque del Alto Mayo LTDA | 4.00% |
| | Cajamarca | Olam Agro Peru S.A.C. | 22.67% |
| | | Cooperativa de servicios múltiples Cenfrocafe S.A.C. | 18.43% |
| | | Compañía Internacional de café S.A.C. | 11.69% |
| | | Louis Dreyfus Company Peru S.R.L. | 10% |
| | | Comercio Amazonia S.A. | 9.13% |
| Centre | Junín | Rainforest Trading S.A.C | 16.95% |
| | | Cooperativa Agroecológica Industrial Juan Santos Atahualpa | 13.51% |
| | | Cooperativa Agraria Cafetalera ACPC Pichanaki | 12.28% |
| | | Kaffee Peru G1 S.A.C. | 11.99% |
| | | Cooperativa Agraria Cafetalera Sostenible Valle Ubiriki | 10.39% |
| | | Cooperativa Agraria Cafetalera la Florida | 9.02% |
| South | Cusco | Agroindustrial y Comercial Arriola e Hija | 20.32% |
| | | Central de Cooperativa Agrarias Cafetaleras Cocla Ltda. Nº 281 | 19.35% |
| | | Cooperativa Agraria Cafetalera Huadquiña Ltda. 109 | 17.35% |
| | | Cooperativa Agraria Cafetalera San Fernando Ltda. | 12.82% |
| | | Coop Agraria Cafetalera José Olaya Ltda | 11.09% |
| | Puno | Cooperativa Agraria Cafetalera San Juan del oro | 58.97% |
| | | Cent. de Coop. Agr. Caf. Valles Sandia LTDA | 41.03% |

Table 1 shows the participation of the main Peruvian coffee exporters, which are located within are located thin inside 6 regions with the highest coffee production. The purpose of this study is to analyze the impact of internal transport within the logistic costs for the export of Peruvian coffee. Besides, a comparative analysis was carried out between Peru and Colombia, on the internal transport costs of coffee exports.

# 4 Results

## *4.1 Analysis of internal transport*

The only internal means of transport for coffee is by land (road), since not all coffee growers have direct access to the boarding exit. The truck is the most used means of transport in the first phase of the growing area to the 100% collection centre, the truck, in the second phase of the collection centre to the processing plant 92.4% and the rented truck, in the third phase of the processing plant to the terminal. Besides, the mule is also an option used by coffee growers [5].

This means of transport is used in the three phases of the coffee journey, these being the first phase from the cultivation area to the collection centre, the second phase from the collection centre to the processing plant, and the third phase from the processing plant to the boarding terminal.

#### 4.1.1 Phase 1 Production area (farm) to the collection centre

In Table 2, it is detailed that the most used means of transport in each section is the rented van, the type of road is unpaved, the state in which it is in greatest proportion is bad, also the average period is between 1.5 and 2.4 hours, and the distance it covers varies according to the stage in the growing area to the collection centre [5].

*Table 2 Characteristics of transport from the farm to the collection centre*

| Phase 1 | Tocache-Zarumilla | Satipo-Callao | Cusco-Callao |
|---|---|---|---|
| **Means of transport** | Rented van (100 %) | Rented van (64.9%) | Rented van (100%) |
| **Type of track** | Not paved (100%) | Not paved (81.3%) | No paved (100%) |
| **Track quality** | Bad (100%) | Good (27.8%) | Bad (100%) |
| **Duration [hours]** | Average 1.5 | Average 2.4 | Average 2 |
| **Distance [km]** | 25.8 | 41.3 | 61.5 |

#### 4.1.2 Phases 2 Collection Centre to Processing Plant

In table 3, it is detailed that the most used means of transport in each section the rented truck, the type of road is asphalted, the state in which it is found in the highest proportion is good, the period on average is between 1.7 and 10.9 hours, and the distance it travels varies according to the section in the phase from the collection centre to the processing plant [5].

*Table 3 Characteristics of transport from the collection centre to the processing plant*

| Phase 2 | Tocache-Zarumilla | Satipo-Callao | Cusco-Callao |
|---|---|---|---|
| **Means of transport** | Rented truck (81.3%) | Rented truck (53.9%) | Rented truck (100%) |
| **Type of track** | Asphalt 87.5%) | Asphalt (100%) | Asphalt (85%) |
| **Track quality** | Good (87.5%) | Good (73.1%) | Good (80%) |
| **Duration [hours]** | Average 1.7 | Average 10.9 | Average 6.5 |
| **Distance [km]** | 109.5 | 350 | 207.2 |

#### 4.1.3 Phase 3 Processing plant to port of arrest

In table 4, it is detailed that the most used means of transport in each section the rented truck, the type of road is asphalted, the state in which it is in the highest proportion is good, he average period is between 2.1 and 28.5 hours, and the distance that it travels varies according to the section in the phase from the processing plant to the port of boarding [5].

*Table 4 Characteristics of transport from the processing plant to the port of embarkation*

| Phase 3 | Tocache-Zarumilla | Satipo-Callao | Cusco-Callao |
|---|---|---|---|
| **Means of transport** | Rented truck (100%) | Rented truck (72.7%) | Rented truck (100%) |
| **Type of track** | Asphalt (75%) | Asphalt (81.8%) | Asphalt (75%) |
| **Track quality** | Good (50%) | Good (100%) | Good (50%) |
| **Duration [hours]** | Average 15 | Average 2.1 | Average 28.5 |
| **Distance [km]** | 401 | 30 | 818.3 |

### 4.2 *Analysis of logistics cost*

Calculations were made for the period 2015-2019, using the FOB price in the main seaport of Peru and breaking down the logistics costs in the process of exporting coffee up to the cost of production, a price was obtained based on the theoretical cost collected from Peruvian Agricultural Exports, also government information was obtained from the Ministry of Foreign Trade and Tourism, where we collected the percentages of the logistics costs of coffee, and the cost of production, this information was used as a reference for comparison between different routes of the exports of coffee where we can see the different logistics costs for each corridor.

Figure 1 shows the percentages that make up the process of the logistical costs of exporting roasted coffee from Peru. Being these, treatment, transport, loading and unloading, transport node, permits and certifications, financial, losses and security, giving a total of 17.23%, 24.23%, 21.56% of the sections Tocache-Zarumilla, Satipo-Callao and Cusco-Callao respectively [5].

*Figure 1 Coffee logistics costs by corridors*
*Source: Developed by the author based on [5]*

In table 5, the fluctuations in exports of roasted coffee beans in the 2015-2019 period, in which, it was analysed that in 2016 USD 754,133,650 was exported in FOB value (placed in the port of shipment) with an average price of USD 3,16, thus becoming the most representative year of the 5 years studied. Likewise, it is observed that in the last three years compared to 2016 exports were decreasing, with a lower price of USD 3 per kilogram [18].

*Table 5 Evolution of coffee bean exports*

| Year | FOB USD Value | Net Weight [kg] | Average price USD/kg |
|---|---|---|---|
| **2015** | 572.137.351 | 172909745 | 3.31 |
| **2016** | 754.133.650 | 238729933 | 3.16 |
| **2017** | 693.876.959 | 240058389 | 2.89 |
| **2018** | 677.191.484 | 259694556 | 2.61 |
| **2019** | 623.317.925 | 228992408 | 2.72 |

### 4.2.1 Cost assumptions

The cost report was made from the study of the Ministry of Transport and Communications (MTC), of the routes identified for the export of roasted coffee, where the following corridors are shown: San Martín-Zarumilla, Satipo-Callao, and Puno-Callao. The steps involved in exporting the coffee to the shipping destination, start from the production areas, collection centre, processing plant, transport and export terminals.

Table 6 shows the estimated production costs (82.77%) and logistics costs (17.23%) of the Tocache-Zarumilla section, in which we identify the procedures that make up the logistical costs in the export of roasted coffee beans is analysed that 20% is for losses, 19% is the financial costs, followed by 18% is treatment and finally, 14% belongs to transport [5].

*Table 6 Assumption of logistics costs for the Tocache-Zarumilla section*

| Tocache–Zarumilla | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Year | | 2015 | 2016 | 2017 | 2018 | 2019 |
| Costs of production (82.77%) | | | 2.739687 | 2.615532 | 2.392053 | 2.160297 | 2.251344 |
| Logistic costs (17.23%) | Treatment | 3.10% | 0.10261 | 0.09796 | 0.08959 | 0.08091 | 0.08432 |
| | Transportation | 2.36% | 0.078116 | 0.074576 | 0.068204 | 0.061596 | 0.064192 |
| | Loading and unloading | 1.98% | 0.065538 | 0.062568 | 0.057222 | 0.051678 | 0.053856 |
| | Port node | 0.60% | 0.01986 | 0.01896 | 0.01734 | 0.01566 | 0.01632 |
| | Permits and certifications | 0.95% | 0.031445 | 0.03002 | 0.027455 | 0.024795 | 0.02584 |
| | Financial | 3.23% | 0.106913 | 0.10206 | 0.09334 | 0.08430 | 0.087856 |
| | Shrinkage | 3.41% | 0.11287 | 0.107756 | 0.098549 | 0.089001 | 0.092752 |
| | Security | 1.60% | 0.05296 | 0.05056 | 0.04624 | 0.04176 | 0.04352 |
| | FOB Average USD/kg | | 3.31 | 3.16 | 2.89 | 2.61 | 2.72 |

Table 7 shows the estimated production costs (75.77%) and logistics costs (24.23%) of the Satipo-Callao section, in which we identify the procedures that make up the logistics costs in the export of roasted coffee beans is analysed that 34% is safety, 24% is the cost of transportation, followed by 15% is of the losses and finally, 8% belongs to loading and unloading [5].

*Table 7 Assumption of logistics costs for the Satipo-Callao section*

| Satipo–Callao | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Year | | 2015 | 2016 | 2017 | 2018 | 2019 |
| Costs of production (75.77%) | | | 2.507987 | 2.394332 | 2.189753 | 1.977597 | 2.060944 |
| Logistic costs (24.23%) | Treatment | 1.99% | 0.065869 | 0.062884 | 0.057511 | 0.051939 | 0.054128 |
| | Transportation | 5.83% | 0.192973 | 0.184228 | 0.168487 | 0.152163 | 0.158576 |
| | Loading and unloading | 2.05% | 0.067855 | 0.06478 | 0.059245 | 0.053505 | 0.05576 |
| | Port node | 0.72% | 0.023832 | 0.022752 | 0.020808 | 0.018792 | 0.019584 |
| | Permits and certifications | 0.84% | 0.027804 | 0.026544 | 0.024276 | 0.021924 | 0.022848 |
| | Financial | 1.07% | 0.035417 | 0.033812 | 0.030923 | 0.027927 | 0.029104 |
| | Shrinkage | 3.53% | 0.116843 | 0.111548 | 0.102017 | 0.092133 | 0.096016 |
| | Security | 8.21% | 0.271751 | 0.259436 | 0.237269 | 0.214281 | 0.223312 |
| | FOB Average USD/kg | | 3.31 | 3.16 | 2.89 | 2.61 | 2.72 |

Table 8 shows the estimated production costs (78.44%) and logistics costs (24.23%) of the Cusco-Callao section, in which we identify the procedures that make up the logistical costs in the export of roasted coffee beans is analysed that 24% is of losses, 23% is the cost of security, followed by 21% is of transport and finally 10% belongs to treatment [5].

*Table 8 Assumption of logistics costs for the Cusco-Callao section*

| Cusco–Callao | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Year | | 2015 | 2016 | 2017 | 2018 | 2019 |
| Costs of production (78.44%) | | | 2.596364 | 2.478704 | 2,266916 | 2.047284 | 2.133568 |
| Logistic costs (21.56%) | Treatment | 2.11% | 0069841 | 0066676 | 0,060979 | 0.055071 | 0.057392 |
| | Transportation | 4.55% | 0.150605 | 0.14378 | 0,131495 | 0.118755 | 0.12376 |
| | Loading and unloading | 2.03% | 0.067193 | 0.064148 | 0,058667 | 0.052983 | 0.055216 |
| | Port node | 0.83% | 0.027473 | 0.026228 | 0,023987 | 0.021663 | 0.022576 |
| | Permits and certifications | 0.69% | 0.022839 | 0.021804 | 0,019941 | 0.018009 | 0.018768 |
| | Financial | 1.11% | 0.036741 | 0.035076 | 0,032079 | 0.028971 | 0.030192 |
| | Shrinkage | 5.27% | 0.174437 | 0.166532 | 0,152303 | 0.137547 | 0.143344 |
| | Security | 4.97% | 0.164507 | 0.157052 | 0,143633 | 0.129717 | 0.135184 |
| | FOB Average USD/kg | | 3.31 | 3.16 | 2.89 | 2.61 | 2.72 |

### 4.3 Analysis of internal transport between Peru and Colombia

According to International Coffee Organization [19], in 2018 Colombia ranked third with 10.44% in the coffee export ranking, making a total of 12808 bags of 60 [kg] each. While Peru ranks in eighth place with 3.31%, making a total of 4064 bags of coffee.

In table 9, we observe that for 2016 Colombia was ranked 94th with a score of 2.6. Unlike 2018, in which it was ranked 58th, climbing 36 positions in the logistic performance ranking of 160 economic, where it also increased its score by 12.6%. The three best performing indicators were infrastructure, international shipping, and logistics competence. Occupying third place below Mexico and Brazil [20].

*Table 9 Logistical performance of coffee-exporting countries*

| | 2016 | | 2018 | | Variation | |
|---|---|---|---|---|---|---|
| Country | Ranking | Score (1-5) | Ranking | Score (1-5) | Ranking | Score (1-5) |
| Brazil | 55 | 3.09 | 56 | 2.99 | ↓ -1 | ↓-3.31% |
| Colombia | 94 | 2.61 | 58 | 2.94 | ↑ 36 | ↑12.60% |
| Honduras | 112 | 2.46 | 93 | 2.60 | ↑19 | ↑5.73% |
| Peru | 69 | 2.89 | 83 | 2.69 | ↓ - 14 | ↓ -6.92% |
| Guatemala | 111 | 2.48 | 125 | 2.41 | ↓ -14 | ↓-2.49% |
| México | 54 | 3.11 | 51 | 3.05 | ↑ 3 | ↓ -2.01% |

Taking into account the information collected from The International Coffee Organization, the World Bank & Veritrade, we chose Colombia, since it is positioned as the second coffee exporting country in South America and since there have been improvements in its score and position with compared to the 2016-2018 period in the logistic performance ranking, unlike Brazil which has experienced drops in previous years. Likewise, it is considered direct competition, because they have characteristics similar to Peruvian coffee, but with marked difference in the sustainability, the price and the consistency of the product. The latter means that in general terms Peruvian coffee continues to be seen as a complement to the offer [21].

Table 10 shows the Global Competitiveness Index (Transportation Infrastructure) for World Economic Forum [22], where Peru and Colombia 65th and 57th respectively in the global competitiveness ranking among 141 countries but rank 104$^{th}$ and 110$^{th}$. While, for the export of coffee, Colombia has another alternative means of transport for the connectivity of land routes, in which it occupies a place in the rail density.

*Table 10 Global Infrastructure Competitiveness*

| Ranking of 141 Countries | | | | | | |
|---|---|---|---|---|---|---|
| | Global competitiveness | Infrastructure | Road quality | Road connectivity | Rail density | Efficiency of the services of trains |
| Colombia | 57 | 81 | 104 | 97 | 88 | 99 |
| Peru | 65 | 97 | 110 | 102 | - | - |

According to K. Alfonso [23], it was stated that the logistic cost of the country is 14.9%, which is above the average for Latin America (14.7%). The survey also found that the highest costs of this field in the country are in transportation and distribution (37%), storage (20%), procurement and management of suppliers (17%), order processing (10%), inventory planning and replenishment (9%) and reverse logistics (7%) (Table 11).

*Table 11 Indicators of internal logistics costs in Colombia*

| **Colombia–14.92%** | | | | | |
|---|---|---|---|---|---|
| Transportation | Storage | Purchasing and supplier management | Processing customer orders | Inventories planning and replenishment | Reverse logistics |
| 37% | 20% | 17% | 10% | 9% | 7% |

One of the differences that exist between Peru and Colombia within the export of roasted coffee beans is the logistics costs (Table 12). Where Colombia presents 14.97% of total sales [23], being smaller compared to Peru that has 21.2% of the total value of the product [4]. The internal transport in Peru and Colombia is between 20.4% and 37% respectively [23,24]. Also, roads are the most widely used type of transport in Peru, while roads and railways are used in Colombia.

*Table 12 Logistical costs of Peru and Colombia*

| | **Peru** | **Colombia** |
|---|---|---|
| **Logistics cost** | 21% | 14.97% |
| **% of internal transport** | 20.4% | 37% |
| **Type of transport** | Terrestrial (road) | Terrestrial (road-rail) |
| **Means of transport** | Truck - Van - Mule | Truck - Van - Jeeps- pack animals - Train (Tertiarization) |

## 5 Discussion

The good climatic conditions and the fertility of its lands for the sowing and harvesting of coffee beans have made Peru one of the main coffees exporting countries in the world due to the great organoleptic properties it possesses. It also has 19 departments, of which only 6 have the largest production of coffee.

Within Peru, the production plants are far from the cities, therefore, a logistics transport system is created for the correct distribution of the goods.

Peru's logistics costs are above the Latin American average (14.7%). The highest costs of this field within the country the transportation (20.4%), decreases (19.2%), and security costs (24%) The best way to see how these costs affect the export of the product is through routes or corridors that start from your production area and reach your export channels. Peru has only one type of land transportation (road) for the mobilization of coffee through its three logistics corridors: Tocache-Zarumilla (San Martín 22.2%, Cajamarca 20.9% and Amazonas 12.5%) connected to the port of Paita; Satipo-Callao (Junín 27.5%); Cusco-Callao (Puno and Cusco 16.8%, in the Quillabamba sub-section) with exit to the port of Callao.

A consequence related to the unstable infrastructure of Peruvian transport, is insecurity, this because vehicles are forced to move slowly along roads in poor condition, which leads to a very tragic situation as they are an easy target for crime [5].

In Peru, 92 per cent of freight forwarders invest in security costs, in the phase from the collection centre to the boarding terminal. Where 69% opt for the mode of insurance for claims and 23% for armed protection. Most of the thefts occur in the vulnerable areas of the capital of Peru, adjacent to the port of Callao, where trucks are usually boarded by criminals while waiting on the access roads to the port.

## 6 Conclusion

This study analysed the documentary information of the internal transport costs for the export of Peruvian coffee, making a brief comparison between the three logistic corridors of coffee production was found that the highest logistical costs are in the corridors of Satipo-Callao and Cusco-Callao, which amount to between 21.26-24.23% of the final value of the product. Compared to the Tocache-Paita corridor, which has a lower logistics cost of 17.23%.

Because not all coffee growers have direct access to the shipping exits, they find it necessary to use the roads as their only means of transportation. In phase 1 from the cultivation area to the collection centre, the state of the roads through which the trucks travel is not paved within the three logistics corridors, while in phase 2 from the collection centre to the processing plant and Phase 3 from the processing plant to the port of shipment have asphalt roads. Thanks to the unstable Peruvian transport infrastructure, freight agents find themselves in need of purchasing various insurance against theft and claims. And all this leads to losses in costs, time, and merchandise.

Making a comparison with Colombia, we can say that both countries present the same problems in the domestic transport in the export of coffee. Due to this problem Colombia added an alternative means of internal transport that is the rail exclusively for the transportation of coffee from the collection centre to the port of boarding. While Peru continues with the same transport system.

For this reason, it is necessary to say that the internal transport has a greater impact on the logistics cost since its excessive costs are due to the deplorable state of the roads where the different means of transport transit and the informality within this process, affecting the final price of Peruvian coffee and the profitability of farmers.

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# MODELLING INNOVATIVE LOGISTIC CLUSTERS FOR REINFORCING INTERNATIONAL ECONOMIC INTEGRATION USING AN EXAMPLE OF A METALLURGICAL COMPLEX

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***Keywords:*** innovation, synergistic effect, logistic cluster, metallurgy

***Abstract:*** The aim of the article is to present the proposed model of an international innovative logistics cluster, which aims to stimulate the renewal of the economic potential of all interested partners with a focus on the metallurgy. Experts analyse ongoing changes and trends that have affected business and logistics processes and define certain trends that could lead to an improvement in the situation, such as the use of a "Cluster strategy". The subject of the research is the analysis of the cooperation between international scientific organizations, research centers and companies within the proposed cluster. A model of the structure of the cluster was created, which will make it possible to monitor global processes in the field of economics and logistics. A simulation of the production of a new product was performed to verify the proposed cluster's expected effects. Therefore, a model was used to determine the value of the company to capture complex links. This model is based on Method DCF using structural analysis principles to objectively evaluate the influence of factors affecting the change of cost potential in the immediate vicinity of the enterprise. During the verification of specific data, the considered project's value was quantified, and obtained results showed that synergy effects could be expected. The verification results show that the interaction and cooperation between universities, research centers, and industrial enterprises at the international level can be made more efficient with an emphasis on effective and lasting cooperation in the field of innovation and technology transfer.

## 1 Introduction

The characteristic feature of the development of a socioeconomic strategy is using a "Cluster strategy." Prof. M. Porter introduced the cluster definition. The clusters were initially based on a given area's competitive advantage, and the corresponding cluster participants were concentrated exclusively on a geographical basis. In his research, Porter emphasized that it is necessary to combine market efforts and concentration, allowing the given companies to achieve great results [1].

Using a sample of 310 cluster companies in Zhejiang, we find that a cluster company will increase its propensity for more geographic cross-border searches than local searches under competitive pressure [1].

Geographic clusters have been recently displaced by a promising new type of clusters - innovative clusters.

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Innovative clusters are particularly typical for industrially developed countries, such as the USA, Canada, Italy, Germany, Czech Republic, and others. However, they are also starting to appear in developing countries, such as India, Brazil, or Russia. This type of the cluster differs because the companies that form a part of the given association do not necessarily have to be located in the adjoining areas. The objectives of such associations are mainly directed towards improving economic competitiveness, developing the given field and technologies, increasing economic activities in the given area, preserving export of products and services, reducing operating expenses and product cost, or securing and preparing highly qualified specialists [3],4].

An analysis of the available works related to the research of "Cluster models" shows that large, medium, and small companies utilize the stated models based on the following basic principles [5]:

- improving technologies and production processes when introducing innovations,
- interaction with educational and scientific and research institutions,
- professional growth of company employees,
- establishment of a unified legal, information, technological, innovative, and financial environment,
- creation of specific general (unified) company business policies and strategies in international economic activities.

The cluster demonstrates that which for some people, at first, may seem paradoxical: that these companies that compete can cooperate if it is a favourable cooperation based on the win-win principle [6].

Cluster policies provide system integration, based on innovations of large, medium, and small companies and other organizations, such as universities and science-research centers. The synergy effect of all partners' activities in the cluster determines the stable, competitive socioeconomic development of the selected industrial fields and territories at the regional and national level and the international level.

The empirical results show that industrial clusters' development attracts and promotes a large number of intermediary service-oriented organizations and institutions providing research and development and technical support, providing an innovative incubation platform. The government's policy should be biased towards establishing an effective mechanism for the interaction between scientific and technological innovation and industrial clusters to achieve a good situation of the interaction between the economy and science and technology [7].

When creating industrial clusters, special attention should be paid to implementing the cluster strategy, interaction among partners, implementing the innovation and investment policies, and optimizing the management of business processes and logistics. This task can be achieved by the modelling of the proposed cluster [8].

The COVID-19 pandemic has led to a worldwide economic crisis. According to the prognosis of the World Bank, it is expected that the gross domestic product (GDP) will significantly drop in 2020 due to the COVID-19 pandemic (Figure 1). Apart from that, it is expected that growth rate will be reduced by more than 13% in 2020 (Figure 2). Due to the blockades related to COVID-19, introduced in many countries, the largest production countries' production sector completely stopped. The industrial production in these countries is linked to the global trading network, and the COVID-19 pandemic led to outages in the supplier-customer chains. The container transport volume significantly dropped due to the reduction of world trade (Figure 3) [9,10].


*Figure 1 Dynamics of global growth*


*Figure 2 Dynamics of trade growth*


*Figure 3 Trends in Container Shipping and Export Orders*

Experts analysed changes and trends from the past that have affected trade and logistic processes and define specific trends that could improve the situation. They include dumping, developing partnerships, cooperation, combining services, implementing the latest I.T. technologies, developing services and partnership contracts, preparing strategies, and post-crisis plans inside the companies [11]. In this work, the attention is focused on specific trends that include the development of cooperation and partnerships in industrial companies, universities, and R&D centers and the introduction of I.T. technologies. Companies are starting to cooperate, develop unique complex offers for customers, and, as a result of that, enforce their joint positions by combining their services. Optimization and digitalization in the area of I.T. technologies have been a discussed topic for a long time. During the crisis related to the COVID-19 pandemic, this trend has become especially important [11].

As the novel COVID-19 pandemic unfolds, it has become necessary to reduce face-to-face contacts, leading to lesser network synergy being produced in an Innovation Cluster. The transformation into a Digital Innovation Cluster, which is less affected by physical distance, but can still maintain the networks' effectiveness, can be the key strategy for the future Innovation Cluster [12].

## 2 Methodology

The cluster theory and innovation logistic cluster's reference model consists of four main blocks, specifically a cluster core, service facilities, and additional and auxiliary objects. These blocks must ensure an innovative character of all cluster members [13]. That is why it is necessary during the first stage of the cluster establishment to determine all blocks' main potential participants.

### 2.1 Cluster core

The proposal envisions that the cluster core will be the Mining University - Technical University of Ostrava. The university is a concentrated source of many skills, bonds, relations, and partnerships. The university cooperates with the public as well as private companies. It actively conducts international education and project engineering activities, and it is a source of highly qualified workers. It also has its center of commercial technologies and sufficient resources. That is why it seems to be a natural choice to select it as the proposal's central core and leader.

### 2.2 Service facilities

Service facilities include communication networks, warehouses, manufacturers of machines and devices, small and medium companies in metallurgy, and energy suppliers. Participants of this block can also be international companies and entities.

### 2.3 Additional objects

Additional objects are companies and organizations of an educational and innovative orientation and other business partners who secure investments and introduce new technologies. This block providing a synergy effect, and the integration of the entire cluster is fundamental. The industrial metallurgy field is strongly developed in the Czech Republic as well as in Russia. That is why Russian universities were also included in the cluster, mainly to conduct employee educational exchanges to generate and spread knowledge. The main participants thus will be companies and research organizations from the metallurgic complex.

### 2.4 Auxiliary objects

Auxiliary objects are optional outsourcing objects. Although this block is optional, the cluster theory allows for significant reductions of the cost of outsourcing of selected processes since incorporation in a cluster creates long-term partnerships, which operate under better financial conditions than individual orders.

Some of the auxiliary objects include customs proceedings and inspections, wholesale companies, insurance companies, security agencies, audit companies, environmental centers, and others.

Apart from that, it is recommended to establish an advisory body for securing interaction between the involved participants and the state and district authorities in the form of a coordination council for strategic planning and for attracting investments for the cluster development. Figure 4 shows the graphic model of the organizational and functional structure of the proposed cluster.

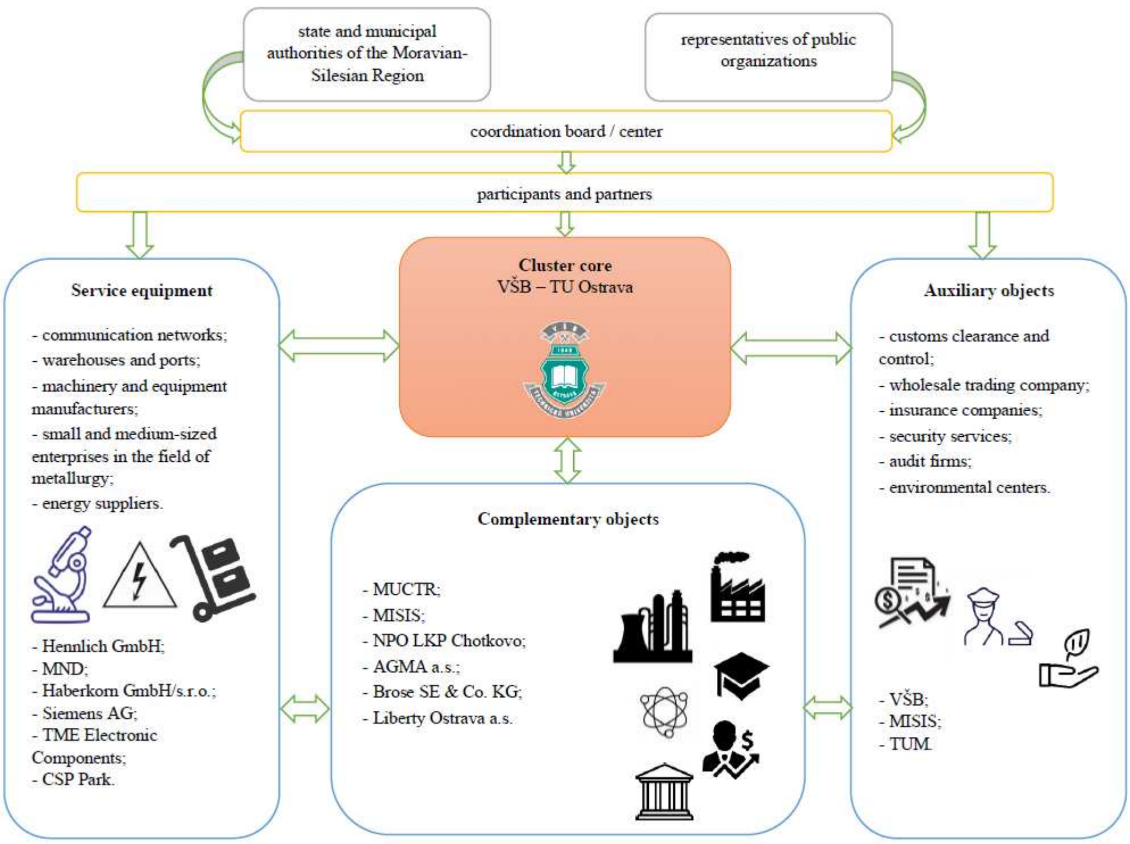


*Figure 4 Graphic model of the organizational and functional structure of the proposed cluster*

A model of the business processes and management needs to be prepared for the cluster's successful operation and development. The proposed information model of the fundamental business processes of the cluster is shown in Figure 5.

The preparation of the model of the proposed cluster's primary business processes revealed a complicated managerial structure. It is necessary to use an instrument to administer information and I.T. technologies to ensure the efficient operation of such complex systems. This model requires computer modelling with the objective of creating a unified information space. The expected consequences of using the proposed model of the integrated logistic cluster stated in Table 1 were analysed to define and assess the economic effects/impacts of the proposed cluster.

It generally applies that the most crucial effect during the early stages of the cluster development is represented by cost reduction and social effect.

An example of an industrial production-research cluster in the metallurgical area was used to verify the proposed cluster's expected effects. The experimental task was to prepare a new, antifriction enamel coating of the defined specifications for use in the aviation field - helicopters. During the production of the stated final product, the key role, i.e. antifriction enamel coating, is played by the chemistry, technology, and metallurgy fields [14].

The analysis was focused on the development of innovative technology at work in the association - enterprise for the production of innovative paints and varnishes Chotkovo (NPO LKP Chotkovo), MUCTR and "Institute for High Purity Substances and Reagents" (part of the Kurchatova Nuclear Research Center) and an extensive economic analysis, which also confirmed the effectiveness of the cooperation of selected entities - the company, MUCTR and the scientific research center "Kurchatova Nuclear Research Center".

A complex and structured production distinguishes the clusters in the industrial sector. That is why it is necessary to have a tool that will make it possible to capture and monitor these complex relations. A tool is needed for calculating production, prices, wages, expenses, etc. in individual parts of the Cluster. Semi-finished products are exchanged among these Cluster parts (internal and external) due to the created relations. Structural models appear to represent a suitable tool that has all attributes for capturing these required relations.

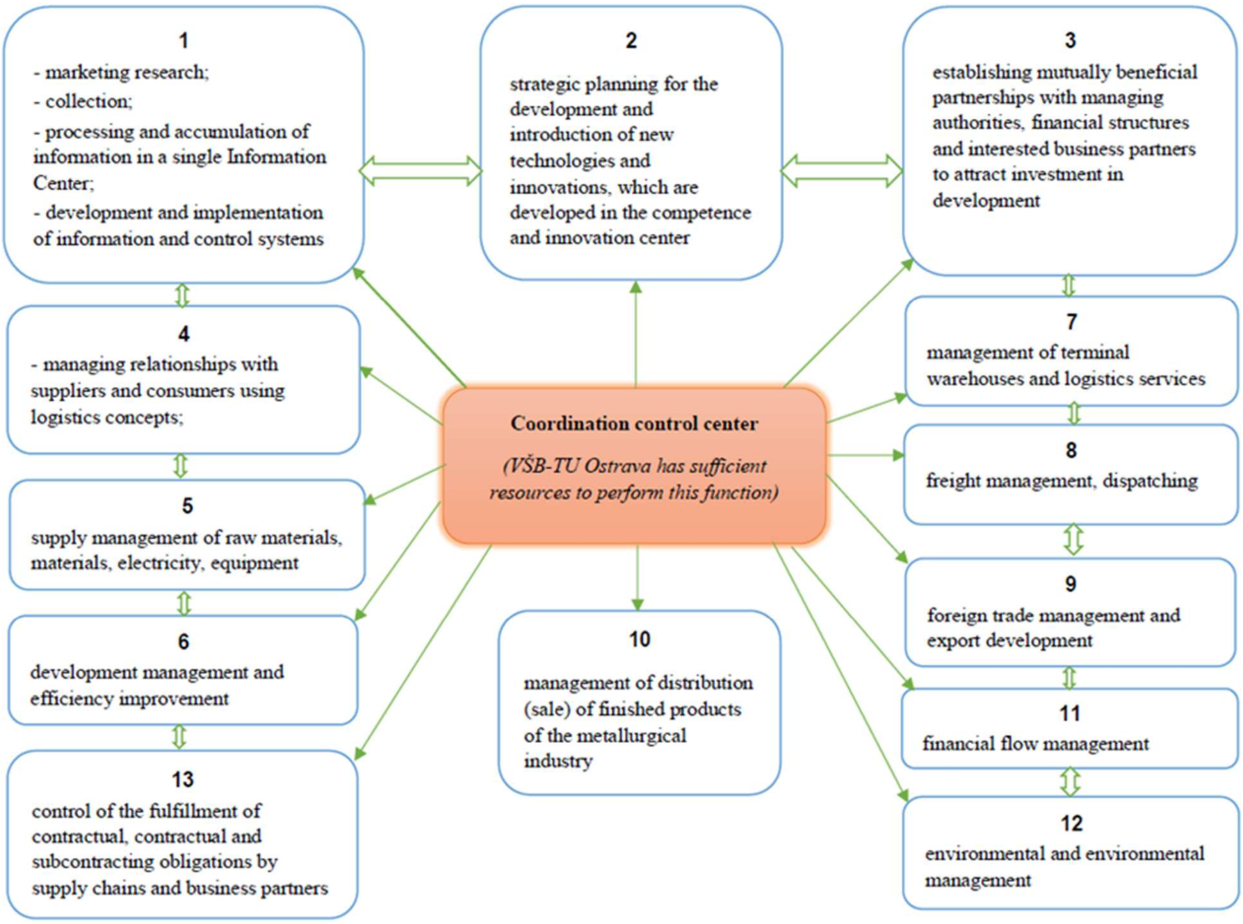


*Figure 5 Proposed information model of the fundamental business processes of the cluster*

*Table 1 Economic effects/impacts of the proposed cluster*

| **Model consequence** | **Effect** |
|---|---|
| Improving the quality of the logistic integration of the participants of the supplier chains based on a harmonization of economic relations and the establishment of partnership, mutually beneficial relations. | Increasing the income and profits of the participating companies through the synergy effect, increasing employee qualification. |
| Reduction of the overall and operation logistic expenses, including cost reduction related to transport and processing time. | |
| Increasing production of the given products. | |
| Improving the quality of the logistic services, increasing the number of services. | Improving the quality of the logistic services. |
| Information and communication reliability, accuracy, and timeliness. | |
| Securing coordination and interaction of individual transport types and other participants based on the creation of a unified space (4PL provider) and the implementation of the information and control systems. | Increasing profit and GDP growth based on the logistic integration and introduction of innovations. |
| Increasing profit and GDP growth based on the growing volumes of the given company productions. | |
| Increasing export of given products. | |
| Securing advanced reproduction and balanced development of the metallurgical industry. | Social effect. |
| Creation of new jobs. | |

Structural models capture the field-to-field balance inside of the proposed system. Wassily Leontief named these models as an "input – output analysis" [15]. It is a descriptive model, the original objective of which was to display reproduction process relations at the national economic level [16]. Nevertheless, the model has gradually expanded to the company level. A structural model of the Leontief type describes the conditions of an equilibrium between the sources and the needs within the modelled system. A structural model of the Leontief type represents a static linear model of an economic system that quantifies the flow of products, raw materials, energy and other production factors inside of any production-consumption system as well as between such a system and its surroundings during the considered time period.

To simulate the synergy effects of the proposed cluster, part of the structural model for determining the value of a given company was used. The model was created based on the DCF method, using the structural analysis principles for an objective assessment of the impact of the factors that affect the potential cost changes in the immediate proximity of the given company [17]. We use Method DCF (discounted cash flow) for valuation of businesses. This method is considered to be the most accurate model for valuing this type of asset, compared to the other available valuation methods (e. g. capital asset pricing model and economic value added).

The following balance (distribution) equations were used for the calculations [18]:

$$X_i = \sum_{j=1}^{n} x_{ij} + Y_i \qquad i,j = 1,2\ldots,n \qquad (1)$$

$$X_i = \sum_{j=1}^{n} x_{ij} + Z_i \qquad i,j = 1,2\ldots,n \qquad (2)$$

where:

$X_i$ - total value production of the $i^{th}$ field ($i = 1,2,\ldots,n$),
$x_{ij}$ - total value consumption of the production of the $i^{th}$ field in the $j^{th}$ -field of the given production-consumption system ($i, j = 1,2, \ldots, n$),
$Y_i$ - total value of the sales of the $i^{th}$ field ($i = 1,2, \ldots, n$),
$n$ - number of fields of the given (production-consumption) economic system,
$Z_i$ - value of primary operating costs of the $i^{th}$ branch (materials, energy, services, wages).

Based on the marketing, production and financial plans and documents from the operative database, a calculation of the revenues and expenses, income statement and Cash Flow for the planned final products - enamelled coating pursuant to various specification - were simulated for the proposed cluster: Enamel 1, Enamel 2, Enamel 3, Enamel 4 for a period of 10 years. Table 2 – 7 shows examples of the executed simulated calculations.

*Table 2 Total value consumption of the production (I. quadrat) and total Y value of the sales (II. quadrat) for time period n*

| I. quadrant | | | | | | | II. quadrant | |
|---|---|---|---|---|---|---|---|---|
| Product | Enamel 1 | Enamel 2 | Enamel 3 | Enamel 4 | Other | | Y | Y |
| | | | | | | | t | Price [EUR/t] |
| Enamel 1 | | 0.645 | 1.121 | | | | 50,000 | 516 |
| Enamel 2 | | | | 1.494 | | | 551,000 | 562 |
| Enamel 3 | | | | | | | 110,000 | 694 |
| Enamel 4 | | | | | | | 32,000 | 938 |
| Other | | | | | | | 31,000 | 1 000 |

In the case of Enamel 1, the coefficients of consumption (specific consumption) of Enamel 1 products are defined in Quadrant I, of which 0.645 tons are consumed to produce one ton of Enamel 2 and 1.121 tons to produce one ton of Enamel 3. In Quadrant II, the slingshot is defined as the sales volume of Enamel 1. The same is true for Enamel 2.

On the basis of these data, the total tonnage of production of the individual products listed in Table 3 is then calculated, which ensures both the mutual consumption of these products resulting from the consumption coefficients listed in Table 2 Quadrant I and the volume of sales of these products to external customers listed in Table 2 Quadrant II.

*Table 3 Total X value of production for time period n*

| Product | Units of measure | X |
|---|---|---|
| Enamel 1 | t | 560,000 |
| Enamel 2 | t | 599,000 |
| Enamel 3 | t | 110,000 |
| Enamel 4 | t | 32,000 |
| Other | t | 31,000 |

Primary operating costs are consumed to produce the products listed in Table 3. Table 4 shows the total *Z* value of primary operating costs, which is based on the sum of material, energy and service costs consumed for the production of individual types of products.

*Table 4 Z value of primary operating costs for time period n (Quadrant III)*

| Operating cost | | | | | | |
|---|---|---|---|---|---|---|
| Products | Units of measure | Enamel 1 | Enamel 2 | Enamel 3 | Enamel 4 | Total costs |
| Material 1 | EUR | 0 | 139,841,122 | 0 | 0 | 139,841,122 |
| Material 2 | EUR | 122,407,426 | 0 | 0 | 0 | 122,407,426 |
| Material 3 | EUR | 61,962,493 | 0 | 0 | 0 | 61,962,493 |
| Material 4 | EUR | - 1,478,484 | 24,355,123 | -2,749,759 | -3,444,643 | -32,028,068 |
| Material 5 | EUR | 14,605,328 | 0 | 0 | 0 | 14,605,328 |
| Material 6 | EUR | 6,006,962 | 0 | 0 | 0 | 6,006,962 |
| Material 7 | EUR | 9,176,473 | 5,491,777 | 782,550 | 204,699 | 15,655,499 |
| Energy | EUR | 19,406,904 | 17,507,259 | 3,604,443 | 196,196 | 40,714,802 |
| Services | EUR | 7,263,520 | 5,859,950 | 1,341,450 | 560,631 | 15,025,551 |
| Total costs | EUR | 239,350,563 | 144,344,985 | 2,978,684 | -2,483,017 | 384,191,115 |

The revenues of the individual products in Table 5 below are based on the values of Table 2 Quadrant II. The operating costs in Table 5 are based on the total costs listed in Table 4. The profit of individual products and the total profit are calculated from the difference between revenues and operating costs.

*Table 5 Income statement calculation for time period n*

| Income statement | | | |
|---|---|---|---|
| Product | Revenues | Operating Costs | Profit |
| | EUR | EUR | EUR |
| Enamel 1 | 25,800,000 | 239,350,563 | -213,550,563 |
| Enamel 2 | 309,662,000 | 144,344,985 | 165,317,015 |
| Enamel 3 | 76,340,000 | 2,978,684 | 73,361,316 |
| Enamel 4 | 30,016,000 | -2,483,117 | 32,499,117 |
| Other | 31,000,000 | 0 | 31,000,000 |
| Total | 472,818,000 | 384,191,115 | 88,626,885 |

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At the end of the baseline period's structural model, the profit of the products (Enamel 1 - Enamel 4) and the whole cluster is known. The total profit of individual years then enters as a fundamental parameter for later determination of cash flow.

*Table 6 Simulated income statement calculation for time period n + 10 year*

| Income statement | | | |
|---|---|---|---|
| **Product** | **Revenues** | **Operating Costs** | **Profit** |
| | thous. EUR | thous. EUR | thous. EUR |
| Enamel 1 | 0 | 79,831 | -79,831 |
| Enamel 2 | 13,708 | 17,032 | -3,324 |
| Enamel 3 | 84,614 | 212 | 84,402 |
| Enamel 4 | 57,152 | 149 | 57,003 |
| Total | 155,474 | 97,224 | 58,250 |

At the end of the structural model in the period n + 10 years, the result of management of individual products (Enamel 1 - Enamel 4) and the whole cluster is known.

The structural model's dynamization was conducted for the subsequent ten time periods. The dynamization is necessary for determining the income statement of the partial periods. The structure of these structural models of individual time periods is identical to the initial structural model structure for the given time period (n). Modelled inputs for the given time period were applied to these structural models. Their definition is not easy and requires significant knowledge and experience when, for example, determining a realistic development prognosis of the planned inputs. As part of the conducted simulation, the expected price increase at the output amounting to 2.0% and the price increase at the input amounting to 1.0% were used.

Simulated income statement and Cash Flow calculations for time period n to n + 10 years is showed in Table 6. During time period n+1, the revenues dropped as a result of the cooperation within the frame of the Cluster due to internal handovers. The expenses decreased due to the cooperation, sharing knowledge, and using individual partners' technologies within the frame of the cluster.

The resulting cash flow used for valuation is then given by the difference between revenues and costs arising from structural models (profit of partial structural models) and by deducting the change in working capital. The calculations show that there is an increase in Cas Flow in the monitored period of 10 years (n + 1 to n + 10) due to the individual partners' cooperation, knowledge sharing, and use of technologies within the cluster (Table 7).

*Table 7 Simulated income statement and Cash Flow calculation for time period n to n+10 years*

| **Period** | **n** | **n +1** | **n +2** | **n +3** | **n +4** | **n +5** | **n +6** | **n +7** | **n +8** | **n +9** | **n +10** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Revenues thous. EUR** | 472,818 | 130,093 | 132,695 | 135,348 | 138,055 | 140,816 | 143,634 | 146,506 | 149,436 | 152,425 | 155,473 |
| Enamel 1 | 25,800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Enamel 2 | 309,662 | 11,470 | 11,699 | 11,933 | 12,172 | 12,415 | 12,664 | 12,917 | 13,175 | 13,439 | 13,707 |
| Enamel 3 | 76,340 | 70,801 | 72,217 | 73,661 | 75,134 | 76,637 | 78,170 | 79,733 | 81,328 | 82,954 | 84,613 |
| Enamel 4 | 30,016 | 47,822 | 48,779 | 49,754 | 50,749 | 51,764 | 52,800 | 53,856 | 54,933 | 56,032 | 57,152 |
| Other | 31,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Operating costs thous. EUR** | **384,192** | **88,896** | **89,785** | **90,683** | **91,590** | **92,505** | **93,430** | **94,364** | **95,308** | **96,261** | **97,224** |
| Enamel 1 | 239,351 | 72,993 | 73,723 | 74,460 | 75,205 | 75,956 | 76,716 | 77,483 | 78,258 | 79,041 | 79,831 |
| Enamel 2 | 144,345 | 15,573 | 15,729 | 15,886 | 16,045 | 16,205 | 16,367 | 16,531 | 16,696 | 16,863 | 17,032 |
| Enamel 3 | 2,979 | 194 | 196 | 198 | 200 | 202 | 204 | 206 | 208 | 210 | 212 |
| Enamel 4 | -2,483 | 136 | 137 | 139 | 140 | 141 | 143 | 144 | 146 | 147 | 149 |
| Enamel 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Profit thous. EUR** | **88,626** | **41,197** | **42,910** | **44,665** | **46,465** | **48,311** | **50,204** | **52,142** | **54,128** | **56,164** | **58,250** |
| **Working capital changes thous. EUR** | 0 | -14,653 | 88 | 90 | 92 | 93 | 95 | 97 | 99 | 101 | 103 |
| **Cash flow changes caused by working capital changes thous. EUR** | **88,626** | **55,850** | **42,822** | **44,575** | **46,373** | **48,218** | **50,109** | **52,045** | **54,029** | **56,063** | **58,147** |

## 3 Result and discussion

The COVID-19 pandemic caused extensive financial difficulties in the area of worldwide trade and logistics. The global financial crisis has forced many companies to address the efficiency of all business processes [19]. Each production and non-production company must continuously look for possible sources of competitive advantages in its processes [20]. One of the possibilities of how to face these negative consequences related to the COVID-19 pandemic is the establishment of specific innovative field clusters (contrary to the classic, geographically-oriented clusters) since the objectives of such field-oriented clusters mostly focus on increasing the economic competitiveness level and on securing the development of the selected field.

A model of an international innovative logistic cluster was proposed as part of the project. Its objective will be to stimulate restoration of all partners' economic potential in the metallurgy area. In order to define and assess the economic effects of the proposed cluster, the expected consequences arising from the proposed model of the integrated logistic cluster were analysed.

Due to the expected flows of information and data, it is recommended to create a unified (shared) information space, which can be implemented, for example, in SAP, enabling effective implementation of research and development activities focused on ongoing cooperation in innovation and technology transfer.

The example of an industrial scientific-production cluster in the field of chemistry and metallurgy was used to verify the expected effects. the innovation process's specific subject was the development of a new anti-frit enamel coating with defined specifications for use in aviation - helicopters. The possibility of making the innovation process more efficient was analysed in order to reduce the costs of product innovation and production processes through the use of synergies from the cooperation between selected research centres and educational institutions and manufacturing companies.

Based on the marketing, production and financial plans and documents from the operational records of stakeholders, the calculation of the plan of revenues and costs, profit and cash flow for the planned final products - enamel coating according to various specifications: Enamel 1 - Enamel 4 was simulated for a period of 10 years.

As part of the analysis, it was found that with the effective cooperation of selected entities, costs can be significantly reduced, for example, for material equipment, tests and human resources, etc., by using the synergistic effect of the cooperation. The calculations show that there was a reduction in costs in the monitored period of 10 years due to individual partners' cooperation, knowledge sharing, and the use of technologies within the cluster. The total profit and cash flow increase within the created cluster during the monitored period (n +1 to n + 10).

The verification results demonstrate the functionality of the proposed model and its suitability for application in economic practice. However, it is necessary to be aware that the expected effects depend on the quality of the entered inputs for a given time period. As we have already stated, input definitions require significant knowledge and skills during the stage when a realistic development prognosis of the planned inputs is being prepared. That is why a precise quantification of the achieved synergy effects depends so much on the quality of the input parameters.

## 4 Conclusions

A typical feature of modern economic development is the transformation of developed countries into a new stage in the formation of innovative companies - building an economy particularly based on the creation, spread and utilization of the given knowledge, i.e. innovative development. The innovation activation process requires fundamental changes in the structure of social production and education and in the management and organization system, as well as action coordination, information exchange, mutual influencing among individual companies and transfer of technologies. From this perspective, it is recommended to use a "strategy cluster", by means of which you can create and use a unified computer information system model for structuring and distributing the tasks of the participants of innovation projects and processes in the production area, which would allow for monitoring the global processes in the areas of the economy, logistics and management of important international centers.

The subject of further research will be an analysis of the cooperation among selected international research organizations, science and research centers and companies, the objective of which will be a simulation of the restoration of the economic potential of all the partners in the area of metallurgy, and the provision of a maximal synergy effect based on innovations and sharing of the economic interests of all participating partners within the framework of the supplier chain.

The following effects are expected within the framework of the proposed international innovative logistic cluster in the area of metallurgy:

- increasing the income and profits of the participating companies by means of a synergy effect, the introduction of innovations and increasing employee qualifications,
- improving the quality of the logistic services of the given participants,
- increasing profit and growing GDP based on the logistic integration and the introduction of innovations.

The most important step during the project commencement stage (cluster establishment) is defining the four main parts of the cluster, and the preparation of a graphic model since such a model allows the potential participants to unambiguously define the roles of all partners included in the cluster. if we consider the expected information and data flow, it is recommended to create a unified information space, which can be implemented in, for example, SAP.

In order to verify the expected effects of the proposed cluster, a production simulation was executed for the new product - antifriction enameled coating pursuant to various specifications for use in the aviation field - helicopters. the conducted calculations and obtained results have demonstrated that it can be expected that the given synergy effects will be fulfilled.

The already implemented project showed that the cooperation of selected scientific organizations, scientific research centers and companies in the field of chemistry and metallurgy brings economic effects. But due to legislative, legal and international restrictions and sanctions, complicated public procurement procedures and the inactive participation of many organizations, it is very difficult for Russian companies and research organizations to establish effective cooperation with foreign partners. We assume that the proposed model will be able to respond to the different legal and legislative conditions of potential collaborating partners - both from the corporate field and research centers and universities.

We believe that the proposed innovative logistics cluster can facilitate the interaction and cooperation of universities, research centers and industrial companies at the international level with an emphasis on effective and continuous cooperation in the field of innovation and technology transfer. the proposed model should be able to define the possibilities and limitations of the cooperation of individual stakeholders relatively precisely to maximize the synergy effect of innovation cooperation while respecting all specific conditions of each country, such as legislative, regulatory and economic.

From a practical point of view, the output of the work will be beneficial, especially for industrial companies. They will be able to use the model to quantify potential economic resources to develop the subject of the innovation process before starting the innovation process in the company, and then start effective cooperation with selected international research centers and educational institutions, realizing research and development activities focused on continuous cooperation in innovation and technology transfer.

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