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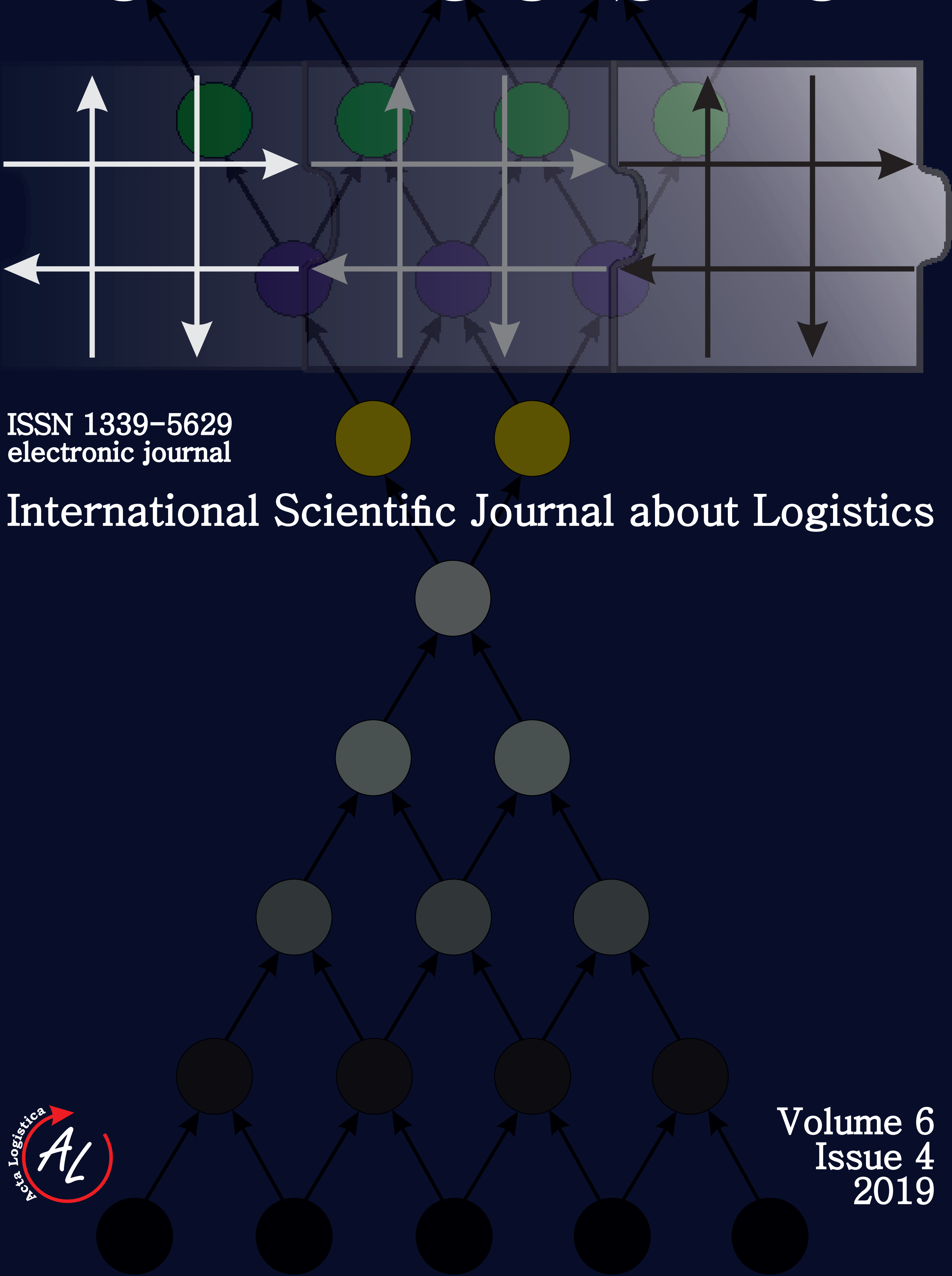

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EVALUATING THE IMPACT OF ORDER PICKING STRATEGIES ON THE ORDER FULFILMENT TIME: A SIMULATION STUDY

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Abstract: A Distribution Centre (DC) is considered a critical node in providing optimal customer service levels in a supply chain network. Therefore, improving order fulfilment time at DCs becomes critical to achieve world-class operations. One of the key processes involved in order fulfilment is that of picking, the activity that consumes most time when fulfilling an order. This article presents the analysis of an actual system that stores products in a random fashion and releases orders following FIFO rules. A simulation model is built, and two scenarios analysed. The first one (baseline) reflects the current DC operation. The second scenario (projected) includes the implementation of three picking strategies aimed at improving system performance: slotting, wave picking, and expedite picking (balancing picker's workload). The following KPIs are used to compare both scenarios: order fulfilment lead-time, picks per man-hour, average picking time per order, average time to pack an order. Simulation results show that the systematic implementation of the proposed strategies achieves substantial improvements, not only in the order fulfilment time (54% reduction), but also in the number of orders completed in less than 8 hours, the number of orders picked per man hour and a reduction of pickers idle time.

1 Introduction

A DC is considered one of the most important nodes in a supply chain network [1], given that its performance has an important impact on the company's profit. A DC is the place where products are received, handled, stored, packaged, and then shipped to satisfy customer orders [2]. To provide a competitive service level at a DC, an order received must be fulfilled in time and quantity; this is often referred to as on-time in-full (OTIF) deliveries [3]. In trying to achieve world-class operations, companies must assess the service level of their DCs through a benchmark with similar industries. A benchmark enables the definition of useful and relevant performance measures based on good practices achieved by best-in-class companies [3]. An example of a benchmark reference is the Warehousing and Fulfilment Process Benchmark & Best Practices Guide [4], which is periodically published by the Warehousing Education and Research Council (WERC). Using this type of information, companies can then make the necessary adjustments and improvements to their processes.

One of the main performance measures in DC operations is the order fulfilment lead-time, defined as the amount of time elapsed between the order is received and shipped from the facility. Since customer orders can be very different from one another, in terms of, for instance, the order mix (high and low volume items), the order lines (number of different items) and the order size (total number of units) [4], it is then important to evaluate the profile of the orders received by a DC in pursuance of defining the best strategies to provide world-class service.

For the fulfilment of an order, a series of activities are performed: picking, packing, and order consolidation. Order picking is a vital and demanding part of the process as it accounts for about 50-75% of the total operating cost for a typical warehouse [5] and utilizes up to 60% of labour force [6]. Additionally, picking comprises one or more of the following processes: batching, routing and sequencing, and sorting. Batching serves as the criteria in which orders are grouped, according to similarities and location, and released for their fulfilment; routing and sequencing determine the optimal sequence in which each Stock Keeping Unit (SKU) is picked; and sorting consists of consolidating orders that are withdrawn together in the same pick wave [7].

The batching process, in particular, requires the planning of the rhythm at which orders are released as well as the determination of the best combination of orders. A common strategy is called `*wave picking*´. A *wave* is a batch of orders that are handled together, optimizing the distance travelled by the staff assigned to the picking process and bringing efficiency into the order fulfilment cycle time [8]. *Wave picking* also benefits from balancing the work between the different processes during the order fulfilment process. Accurately batched and released, *waves* could reduce cycle time by more than 13%, compared to not following any strategy, *e.g.*, orders released as soon as they are received [9].

One of the aspects affecting the batching process is the location of products to be retrieved. Typically, 80% of the orders received at a DC represent up to 20% of the stock-keeping units (SKUs). Focusing on the top 20% products makes a significant difference when planning a DC warehouse layout. The purpose should be to make SKUs reachable and accessible to the zone where orders are consolidated [4]. This layout strategy, for instance, is called *slotting*, in which the storage location is determined based on parameters such as the number of hits or times a product is requested [10]. *Slotting* also considers placing items in the `*Golden Zone*´**,** the ergonomically optimum location (*e.g*., shelves between .5 meters to 1.5 meters from floor) [11]. Even though storage of the products takes longer under this policy, selection of products during order fulfilment is simpler and total lead-time is reduced by optimizing the routing and sequence of the picking process, which has a direct impact on the traveling distance of workers [12].

Picking can also benefit from automated operations. For example, automated storage and retrieval systems (AS/RS). An AS/RS is a system used for the storage and retrieval of products. Its usage may bring several advantages over non-automated systems: reduction of required work force, lead-time and errors during an order fulfilment [13]. The degree of automation of an AS/RS varies from semi-manual devices to computer-controlled robots fully integrated with other warehouse components such as conveyors, automated guided vehicles (AGVs), and warehouse management systems (WMS). Sometimes, despite of the benefits, some companies stick to manual order picking due to variability in SKU shapes and sizes, variability of demand, high seasonality of products, or simply due to the large investment required for such systems.

When evaluating picking strategies, the use of simulation software is valuable. A simulation mimics real-life systems and its process includes “such activities as defining, designing, and constructing a model or representation; defining the experiments to be conducted; collecting and analysing data to drive the model; and analysing and interpreting the results obtained from the experiments” [14]. Therefore, simulation is a valuable tool to assess the efficiency when implementing a new project in a real-life system. [15].

The purpose of this article is to describe a Flexsim simulation model [16] based on the actual DC operations of a Hardware & Tools manufacturer and supplier. This model was used to test the effect of three picking strategies: slotting, wave picking, and expedite picking (balancing picker’s workload). Currently, the company does not perform slotting (products are stored in a random fashion, with no other strategy than size and weight), its orders are released following FIFO rules (no *wave* strategy), and picking operators are assigned to one or more aisles and they are not allowed to pick items from other aisles even if they are idle (causing an uneven workload distribution).

This article is organized as follows. Section 2 presents a review of related literature. Section 3 describes the DC operation and simulation model specifications. Section 4 presents the experimental design, KPIs and proposed simulation scenarios. Results are discussed in Section 5. Conclusions and further research ideas are presented in Section 6.

2 Literature Review

Order picking is a topic that has been extensively studied in research over the last decades. The primary focus has been mostly on comparing the effectiveness of different picking policies. Picking policies determine which SKUs are placed on a pick list for later retrieval from storage locations. Storage location assignment, batching and routing are the core operating policies that are considered when assessing picking systems at warehouses [17]. Strict-order picking is a common policy that consists in touring through the warehouse to pick all SKUs for a single order [18]. The advantage of that policy is that it maintains order integrity and simplifies sorting. Combining several orders into batches is another policy that has been extensively studied throughout the years [19-21].

Petersen and Aese [18] performed a Monte Carlo simulation to assess the impact of the three core picking policies, comparing the current operation of a firm (baseline) between 27 combinations of picking policies. They concluded that batching orders is the policy that brings about the largest reduction in picking time, but assuming that orders did not need a later sorting process. While class-based storage also reduced the picking time, complex routing can cause confusion and affect the performance of the entire system.

Dekker et al. [22] studied a Tools Wholesaler with the purpose of improving order picking through the use of storage and routing policies. With the help of a simulation model they evaluated 18 combinations of storage and routing policies, obtaining reductions of up to 28.9% of pickers’ travel distance and 4% in picking time.

Manzini et al. [23] proposed travel distance as the KPI to assess a picker-to-part picking system using simulation. Through plenty of industrial data, they concluded that routing policy is the factor that contributes the most to the improvement of the system performance. Class-based storage also helped to reduce the picking cycle time.

Dukic and Oluic [24] used simulation to explore the three core operating picking policies (batching, storage, and routing) using a basic layout of a conventional warehouse. They achieved considerable decrease in travel distance when combining batching and volume-based storage. Additionally, integrating routing as part of the picking policy did not have an important impact on performance.

Chackelson et al. [25] presented a research-based case of a warehouse with delivery times ranging from 24 to 48 hours. Using simulation software, they analysed the interaction between different batching, storage, and routing policies. They found that using a class-based storage policy, return routing method and releasing orders by batches (pick by article), improved the total picking time.

In terms of order lead time, Pedrielli et al. [26] developed an algorithm to generate a picking list (wave picking). They also established a zone picking strategy, where orders were broken in items located at the same storage zone and assigned to a picker (balancing workload). Finally, items were sorted at end of the picking process to the matching order. Using discrete event simulation and picking cycle time per item as the main KPI, the algorithm and strategies were evaluated, showing important improvements in the system performance.

Lead-time optimization and picking work load were the subject of study for Wasusri and Theerawongsathon [27], where the performance of a real basic DC layout was analysed contrasting different picking policies. The results showed a decrease in picking time through batch and zone picking and a better staff utilization. Policies like routing and storage were not studied in this paper.

Using a genetic algorithm integrated in a cloud-based system, Leung et al. [28] consolidated orders and generated operating guidelines based on storage location, weight and volume of items. Through the provision of picking lists to perform batch picking, the order processing time (lead-time) and traveling distance were reduced significantly. No other DC policies aside from batch picking were studied.

The common aspects of the cited research are: they study basic DC layouts, except for Chackelson et al. [25]; they only considered picking time as part of order fulfilment time, except for Pedrielli et al. [26] and Leung et al. [28], excluding other processes such as packing, sorting, and consolidation. For that reason, we study a system with a complex layout (a semi-automated DC that includes picking zones with different configurations) where picking, packing, sorting and consolidation processes times are considered as part of the order's fulfilment time.

3 System description and simulation model

The simulation model analysed in this research has been built based on the DC operations of a Hardware & Tools manufacturer and supplier. Nowadays, the fast growth of e-commerce companies like Amazon has become a threat to the economic stability of this kind of companies. Despite its efforts to improve speed of response through implementation of an AS/RS system, performance is not yet competitive. For that reason, the company under study is looking for strategies to improve its order fulfilment process (picking, packing, and consolidation) in order to achieve world-class standards. In particular, the DC needs to expedite the order fulfilment process, using only current resources (operators and infrastructure). As stated in the Warehousing and Fulfilment Process Benchmark & Best Practices Guide [4]: "*in pursuance to achieve a best-in-class customer service level, the average time from order placement to shipment must be less than or equal to 8 hours*"

3.1 DC Operation

The DC receives orders from different customers that range from transnational retailers, such as Wal-Mart, to final individual customers. The order mix, size, and lines vary considerably, complicating the order fulfilment. Based on historical data, Table 1 shows the number of lines per order and their probability of occurrence.

Table 1 Order lines and their probability of occurrence

ORDER LINES	PROBABILITY *P(X)*
1-2	.13
3-5	.12
6-10	.17
11-20	.19
21-50	.29
51 OR MORE	.1

The DC works 24/7. The average number of orders received per day is 400, which translates into approximately 9,500 order lines to be picked daily. Once an order is received, it is released following FIFO rule. Figure 1 shows the order fulfilment process:

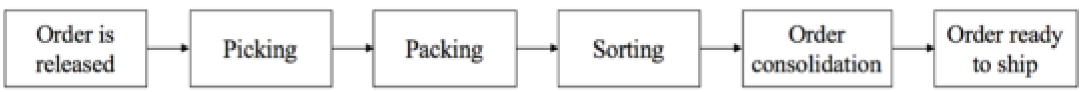

Figure 1 Order Fulfilment Process

The order fulfilment process takes place within 7 defined zones (see Figure 2):

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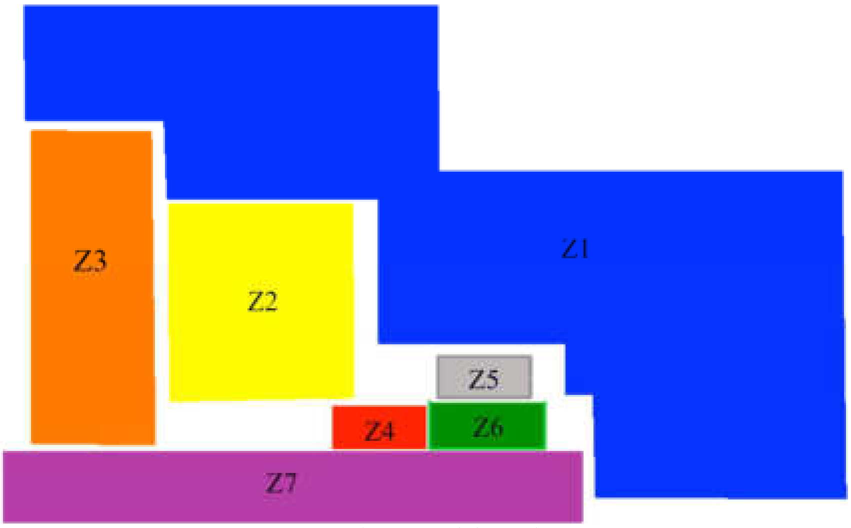

Figure 2 DC layout and defined zones

- Picking
  - Zone 1 (Z1): Storage of medium and large items (objects with a volume greater than 90,000 cm^3, such as hydraulic jacks and high-pressure compressors).
  - Zone 2 (Z2): Storage of small items (objects with a volume between 24,000 cm^3 and 90,000 cm^3, such as drilling machines and tool boxes).
  - Zone 3 (Z3): AS / RS (objects with a volume below 24,000 cm^3, such as dies and screwdrivers).
- Packing
  - Zone 4 (Z4): Packing 1, for orders with 1 or 2 order lines and items picked from AS/RS and small items picking zones.
  - Zone 5 (Z5): Packing 2, for medium items.
  - Zone 6 (Z6): Packing 3, for orders with 3 or more order lines and items picked from AS/RS and small items picking zones.
- Sorting & consolidation
  - Zone 7 (Z7): 11 different docks are located at the south area of the DC; different items of the same order are consolidated for later shipment.

Items flow between packing zones (Z4, Z5 and Z6) and order consolidation & loading (Z7) using a conveyor and a sortation system (see Figure 3).

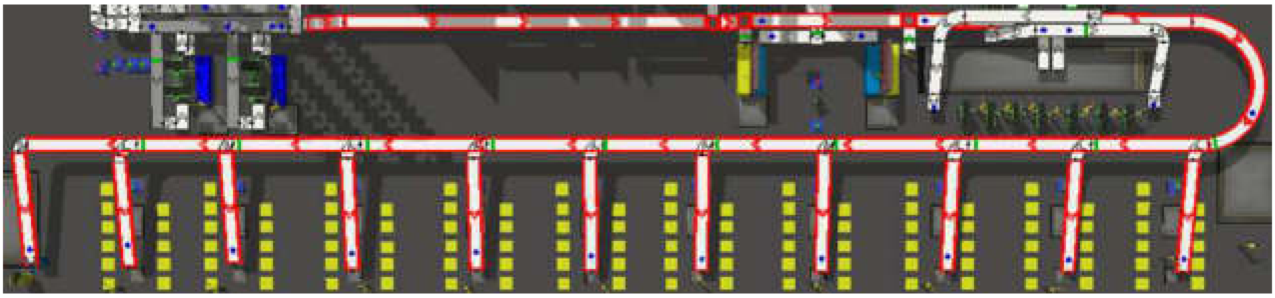

Figure 3 Conveyor and sortation system

3.2 Simulation Model: Specifications

Input information for simulation model was retrieved from 6,758 real orders (154,325 picks) fulfilled at the DC from 16th to 31st of March 2018. Flexsim's Expert Fit module was used to statically analyse data; Chi-square test was performed to assess the goodness of fit of the obtained statistical distributions.

3.2.1 Operators

A total of 46 operators (Table 2) are involved in the fulfilment process. Dispatcher objects and process flow tools are used in the simulation model to control the sequence of the operators' tasks.

Table 2 Flexsim Operators (Resources) Configuration

OPERATION	ZONE	NO. OF RESOURCES	LOAD TIME (SECONDS)	UNLOAD TIME (SECONDS)	TRAVEL VELOCITY EMPTY (M/S)	TRAVEL VELOCITY LOADED (M/S)
PICKING	Medium and large items	5	N(14.8,4.9,0)	3	2	2
PICKING	Small items	15	N(15.55,4.41,0)	N(4,.98,0)	1	1
PICKING	AS/RS	2	0	0	2	2
PACKING	Packing 1	4	1	1	2	2
PACKING	Packing 2	2	0	0	2	2
PACKING	Packing 3	7	0	0	2	2
ORDER CONSOLIDATION & LOADING DOCKS	Consolidation	11	0	0	2	2

Notes:
1. Loading operation, performed by freight carriers, is out of scope of this simulation.
2. Picker operators use buckets to retrieve small products and dollies for large and medium items.
3. N(mean, standard deviation, stream)≈Normal distribution.

3.2.2 Picking zones

The picking of items takes place amongst three different zones, each one with particular features:

- Storage of medium and large items (Z1):
  - 40 rack objects of different dimensions are used to emulate the storage of medium and large items. These items do not stream through the conveyor and sortation system.
  - Picking process time is composed of the time the picker uses to load, transport and unload a requested item.
  - Once a picker completes an instruction, picked items are sent, using dollies, to Packing 2 (Z5) (medium items) or to order consolidation & loading zone (Z7) (large items).
- Storage of small items (Z2):
  - This zone is a multi-storey warehouse (see Figure 4) with a very low percentage of automation.
  - Each story has 6 rack objects and 6 queues (staging zones) where picking process is simulated.
  - Picking time follows a uniform distribution with a lower limit of 7.81 seconds and an upper limit of 13.33 seconds.
  - Picking process, of an order line, is started when there is an available picker operator.
  - Once a picker completes an instruction, picked items are sent in buckets, through conveyors, to Packing 1 (Z4) or Packing 3 (Z6).

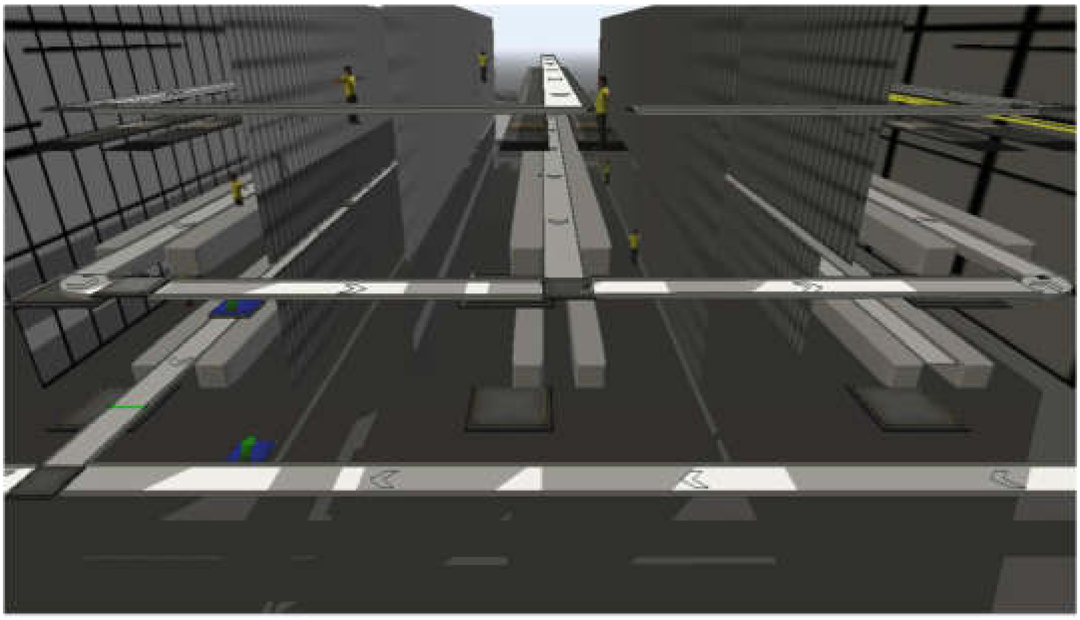

Figure 4 Flexsim representation of the multi-storey warehouse

- AS/RS (Z3):
  With the objective of a more realistic emulation of the AS/RS, several other Flexsim's objects were used to build system (see Figure 5):
  - 4 **racks**, with an available aisle between each pair of racks. Each rack has 2000 positions for storage.
  - Each aisle has an elevator that stores/retrieves bins. The elevator transports bins through the different rack's bays and levels. This elevator was simulated using 20 Basic Task Executer objects and illustrated with spheres.
  - At ground level (Figure 5), 2 picking stations are located, each of them was simulated using 6 processors, a queue and an operator.
  - The picking process time follows a discrete uniform distribution with a lower limit of 3 seconds and an upper limit of 10 seconds. A conveyor is used to transport items between racks and the picking stations (velocity = 0.17 m/s).

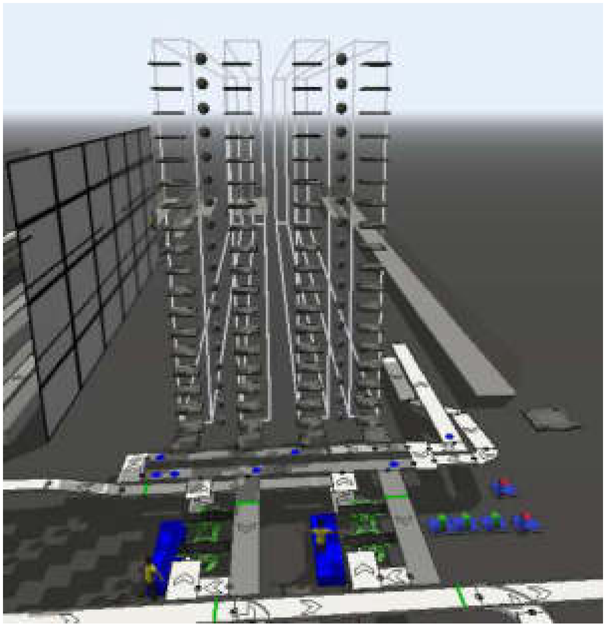
Figure 5 Flexsim representation of the AS/RS

3.2.3 Packing zones

Picked items are transported to 3 different packing zones, depending on the characteristics of the order and the size of the items. Following is a description of each packing zone:

- Packing 1 (Z4):
  At this location items belonging to orders with 1 or 2 lines, picked from the AS/RS (Z3) or small items storage zone (Z2), are packed. Several Flexsim objects were used to simulate the zone:
  - 2 input conveyors for items coming from the AS/RS (Z3) or the small items storage zone (Z2).
  - 2 queues, where items wait until a packing operator is available.
  - 2 separators, to separate items from picking buckets. Items are packed, and buckets are released to picking zones.
  - 2 racks, to put together items of a same order that arrive in different buckets. The racks emulate a pick to light system.
  - 2 combiners, to pack items in boxes. The process time follows a normal distribution with a mean of 34.6 seconds and a standard deviation of 6.69 seconds.
  - 2 output conveyors that transport the packed items to the sortation system.

- Packing 2 (Z5):
  Medium items are packed at this location. Several Flexsim objects with specific tasks were used to simulate this zone:
  - 1 queue, where items waits until a packing operator is available.
  - 2 processors, which pack items following a normal distribution with a mean of 50 seconds and a standard deviation of 10.9 seconds.
  - 2 output conveyors that transport the packed items to the sortation system.

- Packing 3 (Z6):
  At this location items belonging to orders with 3 or more order lines, picked from the AS/RS (Z3) or small items storage zone (Z2), are packed. Several Flexsim objects were used to simulate the zone:
  - 2 input conveyors for items coming from the AS/RS (Z3) or the small items storage zone (Z2).
  - 1 queue, where items wait until a packing operator is available.
  - 7 processors, which pack items following a normal distribution with a mean of 35 seconds and a standard deviation of 7.8 seconds. A setup of 35 seconds is performed at each processor, every fifth item.
  - 2 output conveyors that transport the packed items to the sortation system.

3.2.4 Conveyor and Sortation System

When an order is fulfilled through batch picking, items need to be sorted and then consolidated in a determined area. This sortation can be performed with the assistance of an automated system of conveyors [3]. Additional to the conveyors, control mechanisms and software are integrated to transport and assort items through the facility. The DC's conveyor and sortation system were emulated using the following configuration:

- The velocity of the conveyor and sortation system is 0.37 m/s.
- The following areas are inputs to the conveyor and sortation system: Small items storage zone (Z2), AS/RS (Z3) and all packing zones (Z4, Z5 and Z6).

- The final section of the conveyor and sortation system is composed by 11 ramps (Flexsim conveyors) that transport the packed items into the order consolidation area.
- Many decisions points are located through all the system to manipulate the flow of items (Figure 6).

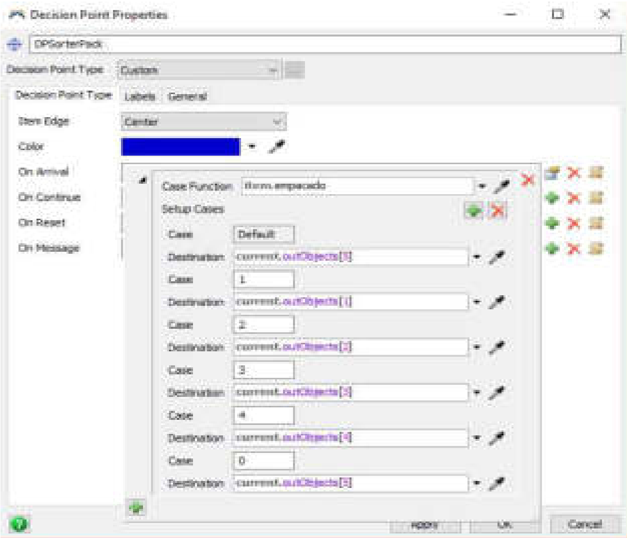

Figure 6 Conveyor and sortation system configuration

3.2.5 Consolidation and loading docks

In this area of the model, the packed items are routed to 11 different consolidation/loading docks, according to the order they belong and the freight carrier that will be used to ship to customer. The following Flexsim objects were employed to build each consolidation/loading dock:

- 4 queues.
- 15 combiners, where 15 different orders can be consolidated at the same time.
- 1 source to create the pallets that serve as a container to all the order lines consolidated in their correspondent order.
- 1 sink, serving as the final destination for orders at the DC, and where their fulfilment time ends.

Notice that loading of trucks and shipping is out of scope of this study.

4 Experimental Design

4.1 Key Performance Indicators

Since the primary goal for the company under consideration is to achieve a best-in-class customer service level, through expedited fulfilment of orders, we measure the **order fulfilment time**. This time includes: picking, packing, sorting and consolidation processes.

Additionally, other KPIs were also used to evaluate the effectiveness of the proposed strategies:

Order lines picked per man-hour: this indicator measures workload and velocity of pickers.

Average picking time per order: picking is the most time-consuming activity in the fulfilment of an order, having a performance indicator isolating this process can help to contrast with the order fulfilment lead-time.

Picker's idle percentage time: this indicator helps to assess the balance of workload between operators.

4.2 Strategies and Scenarios

Three main strategies are proposed to optimize the system performance:

1. **Slotting**, storage of SKUs following a class-based logic.
2. **Wave picking**, batching similar orders using different criteria such as location of SKUs.
3. **Expedite picking** through balancing pickers workload. Levelling the assignment of tasks among pickers releases possible bottlenecks.

Two scenarios were analysed:

1. **Baseline**, which represents the current operation.
2. **Projected**, which considers the implementation of the proposed strategies, in conjunction, based on the research of Dukic and Oluic [24] and Chackelson et al. [25].

15 days of historic orders are simulated, for both scenarios, using Flexsim sources with scheduled arrivals. It is assumed that the infrastructure and human resources remained the same for both scenarios. The implementation of each strategy in both scenarios is now explained in more detail:

4.2.1 Strategy 1: Slotting

- Baseline scenario:

There is no slotting; products are stored in a random fashion, with no other strategy besides their size and weight. Of the total order lines, 19% are stored in the medium and large items storage zone (Z1), 61% in the small items storage zone (Z2) and 20% in the AS/RS (Z3).

- Projected scenario:

Items were classified following an ABC system based on two criteria:

1. Frequency, the number of times an item is requested in a given time period (three times a day, daily, weekly, monthly).
2. Hits, the number of daily picking events for an item.

The second criterion is used to consider the times a picker travels to an item location, depending on the item's requested quantity by an order. This is important to be weighted given that some items only need one picking event per order, while others need several picking events, affecting the distance travelled by a picker to fulfil an order.

25 item categories were identified, and slotting was modelled by picking zone following the next approaches:

- Medium and large items storage zone (Z1): items with a higher hierarchy are placed in the "Golden Zone" and at locations near packing. These items are also distributed through parallel racks to avoid pickers traffic.
- Small items storage zone (Z2): items with a higher hierarchy are placed in the "Golden Zone", at the north side of the picking zone in order to facilitate the replenishment of inventory.
- AS/RS (Z3) was considered out of scope of the slotting strategy.

4.2.2 Strategy 2: Wave picking

- Baseline scenario:

Orders are batched in groups of 150, following only FIFO rules.

- Projected scenario:
  Orders are batched and released for fulfilment using the following criteria:
  - Order size (number of order lines). Orders with only 1 or 2 lines are given priority.
  - Order line aisle location. Pickers are given order lines placed in a same aisle with the objective of minimizing travelled distance.
  - Order line weight. Buckets are used in Z2 to transport picked items. Ranking order lines based on weight contributes to less buckets flowing along the DC.
  - Order line ABC category. Orders with items with higher frequency/hits are given priority during picking operation.

With the purpose of avoiding saturation of the conveyor/sortation system, waves are made up of maximum 250 orders.

4.2.3 Strategy 3: Balancing picker's workload

- Baseline scenario:
  Operators are assigned to fixed aisles in all zones; if they are idle, they cannot pick items from other aisles. A study of utilization of different picking operators in the current system discovered that pickers in the medium and large items storage zone (Z1) have unequal workloads.

- Projected scenario:
  Pickers in the medium and large items storage zone (Z1) are not assigned to fixed aisle(s), they can pick from any aisle in order to expedite picking.

5 Results

Table 4 shows order fulfilment time per order. Notice that there is a reduction of 55% in the average order fulfilment time per order by implementing the proposed strategies. Yet, the maximum time achieved by the projected scenario is equivalent to 12.56 hours (754.1 min). This time is still far above the best in class expected time (8 hours), however if we segment the number of orders completed by time ranges (see Table 5), we observe that while only 35.8% of Baseline Scenario orders (149 of 416) are completed in 8 hours or less, 93.9% of the orders (391 of 416) are fulfilled in 8 hours or less in the projected scenario, contributing mostly to a best-in-class customer service level.

Table 4 Order fulfilment time (min) per order

	BASELINE SCENARIO	PROJECTED SCENARIO
MINIMUM	1.1	1.55
MAXIMUM	1224.31	754.1
AVERAGE	503.74	225.09

Table 5 Number of orders completed in given time ranges

	BASELINE SCENARIO				PROJECTED SCENARIO		
ORDER LINES PER ORDER	0-8 hrs.	8-16 hrs.	16-24 hrs.	Total	0-8 hrs.	8-16 hrs.	Total
1-2	57	6	0	63	63	0	63
3-5	30	20	1	51	50	1	51
6-10	30	46	1	77	76	1	77
11-20	21	60	3	84	83	1	84
21-50	9	77	10	96	90	6	96
50 OR MORE	2	34	9	45	29	16	45
TOTAL ORDERS	149	243	24	416	391	25	416

The studied DC has automated equipment that accelerates the fulfilment of orders, but the process also relies on 46 operators. The proposed strategies benefited the manual tasks making the workforce more productive. Table 6 shows the **order lines picked per man-hour** for both scenarios. Notice that there is an improvement of 69.25% (on average) in the pickers productivity, in accordance with the reduction of the time needed to fulfil one order.

Table 6 Order lines picked per man-hour

	BASELINE SCENARIO	PROJECTED SCENARIO
MEDIUM & LARGE ITEMS PICKER 1	16.81	49.75
MEDIUM & LARGE ITEMS PICKER 2	16.23	49.56
MEDIUM & LARGE ITEMS PICKER 3	29.96	33.71
MEDIUM & LARGE ITEMS PICKER 4	30.03	33.46
SMALL ITEMS PICKER 1	22.07	38.27
SMALL ITEMS PICKER 2	21.63	37.88
SMALL ITEMS PICKER 3	21.65	38.18
SMALL ITEMS PICKER 4	21.11	36.90
SMALL ITEMS PICKER 5	20.39	37.51
SMALL ITEMS PICKER 6	22.04	35.93
SMALL ITEMS PICKER 7	22.05	36.12
SMALL ITEMS PICKER 8	22.02	35.83
SMALL ITEMS PICKER 9	22.23	35.59
SMALL ITEMS PICKER 10	22.10	35.88
SMALL ITEMS PICKER 11	23.85	38.29
SMALL ITEMS PICKER 12	23.96	38.44
SMALL ITEMS PICKER 13	24.05	38.31
SMALL ITEMS PICKER 14	23.86	37.75
SMALL ITEMS PICKER 15	23.94	38.18
AS/RS PICKER 1	31.94	55.83
AS/RS PICKER 2	29.65	50.77
AVERAGE	23.41	39.62

As stated before, the most demanding activity in the order fulfilment process is the picking time per order. Table 7 shows a comparison of the picking time per order for both scenarios.

Table 7 Picking time (min) per order

	BASELINE SCENARIO	PROJECTED SCENARIO
MINIMUM	0.16	0
MAXIMUM	1209	733.52
AVERAGE	491	205.5

The proposed picking strategies help to achieve a reduction of 58% on average picking time. As well if the average picking time is compared with the total time to fulfil an order (Table 4), we can see that during the 91.29% (205.5/ 225.09) of the time it takes to fulfil an order, picking process is being executed, which supports that this is the most time-consuming activity in the fulfilment process.

Levelling labour workload for pickers in the medium and large item picking zone (Z1) has an important effect on the percentage of pickers idle time (see Table 8). In the baseline scenario, the idle percentage time between pickers varies by 49% (20% vs. 69%); whereas in the projected scenario, it only varies 1% (3% vs. 4%). Also, it is clear that the idle percentage with respect to other activities in both scenarios is considerably different, being much lower in the projected scenario. This is because more orders are fulfilled throughout the day, increasing the workload for all pickers.

Table 8 Operators' utilization

	BASELINE SCENARIO					PROJECTED SCENARIO				
OPERATORS	Travel empty	Travel loaded	Loading	Unloading	Idle	Travel empty	Travel loaded	Loading	Unloading	Idle
PICKER 1	9%	21%	5%	1%	65%	3%	42%	48%	4%	3%
PICKER 2	7%	19%	5%	0%	69%	3%	42%	48%	4%	3%
PICKER 3	5%	40%	30%	2%	23%	5%	56%	32%	3%	4%
PICKER 4	5%	41%	32%	2%	20%	5%	56%	33%	3%	4%

From the results above and as measured by the defined KPIs, we observe that by implementing the proposed picking strategies the company achieved a better performance. The reduction in order fulfilment time provides the company with the opportunity to potentially manage and satisfy an increased number of current customer orders or open new markets to additional customers. In fact, the implementation of the proposed strategies will allow the company under study to take some orders from important customers that had not been taken previously because of the inability to respond in a timely fashion. Moreover, the company knows that to stay alive in their competitive market, they need to continue to implement world-class initiatives, like the proposed in this study.

Likewise, improving the number of order lines picked per man-hour, in particular, translates into greater employee productivity, reducing idle time while increasing resource utilization. This again may bring some extra benefits such as: increase the ability to receive and satisfy more orders, increase company's profit, which ultimately, could serve to provide more competitive salaries and wages to employees. In general, there are many economic advantages that may result from reducing order fulfilment time: significant reduction in inventory, less variability in the demand, less expedited orders, among others. This eventually becomes a virtuous cycle, by carrying fewer inventories and improving its processes in a continuous basis, companies may be able to reduce fulfilment time further.

6 Conclusions

In this paper the impact of three picking strategies (slotting, wave picking and levelling labour's workloads) on order fulfilment time is evaluated on an actual Hardware & Tools manufacturer DC via simulation. Two scenarios are evaluated: a baseline scenario, which represents the current operation; and a projected scenario, which considers the implementation of the proposed strategies.

Simulation results show important improvements when implementing the proposed strategies: 55% decrease in average fulfilment time; 70% increase on the number of order lines picked per man-hour; 58% reduction in average picking time; and idle time is also reduced as pickers fulfil a larger number of orders. Recall that these improvements were achieved by keeping the same infrastructure and human resources. In general, there are many economic advantages that may result from reducing order fulfilment time: significant reduction in inventory, less variability in the demand, less expedited orders, among others.

Although the combination of the three picking strategies achieve important results, only 94% of the orders are completed in less than 8 hours, which is the world-class standard pursued by the company. Further studies are needed to develop strategies that help achieve 100% of orders completed in less than 8 hours. Some potential strategies for future work are the following: Slotting strategy for items stored at AS/RS (Z3), balance workload of all picking zones (Z2 and Z3), (the current study only considered this strategy for the medium & large items storage zone (Z1)) and lastly, analyse and propose different picking strategies when orders of 50 or more order lines are received (this type of order is yet out of the 8 hours standard).

Finally, even though the focus of this research is on measuring response time to costumers, future studies should be conducted to evaluate quality-oriented KPIs, such as fill order rate and customer satisfaction.

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THE DEVELOPMENT OF THE INNOVATION STATUS AND IMPACT OF SMART PACKAGING ON SLOVAK CONSUMERS

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Abstract: The decision about packaging belongs to the most substantial product characteristics. It has impact on the quality of food as well as shopping preferences of consumers. Because the significance of packaging keeps increasing, companies need to take a more innovative approach to packaging policy in the context of ecological innovations. The food packaging industry is largely subject to change from passive to innovative packaging resulting in making the smart packaging. The producing companies, processors of food, logistic operators as well as consumers constantly ask for more innovative packaging (smart packaging) to make products that fulfil standards in the area of quality, safety or identification of products within the logistic chain. The research of understanding and attitudes towards smart packaging as well as evaluation of its utility and requirements was used by the Kano model concept. The aim of the paper is to determine the development of innovation status and the impact of smart packaging on consumers in different age categories in Slovakia. The results show the positive impact of smart packaging on Slovak customers. Innovation status of smart packaging among Slovak customers in determined age categories has increased during the monitored period and younger respondents evaluate the smart packaging as an added value of the product. This added value of smart packaging supports the smart logistics to make the whole logistic chain more effective to develop a decentralized database storing the constantly increasing number of various records, such as product movement or its quality.

1 Introduction

The issue of foods packaging is a significant sphere during the processing of food [1] and nowadays it is essential to make changes in this area, especially to make it from inactive to more innovative. The new requirements in packaging should meet global trends, advances in the technological area and requirements of consumers [2-4]. Traditional packaging of food is created to eliminate the negative impacts of the environment on the product [2]. On the other hand, innovative packaging is aimed to raise the consumer´s life standards through improved nutritious, health features of the product offered in more attractive design. Non-traditional packaging functions prolong durability, improve quality, safety of food products and make them also environmentally friendly [5-7]. They consequently reduce the number of complaints from sellers and consumers [8].

Therefore the aim of this paper is to determine the development of the innovation status and the impact of smart packaging on consumers in different age categories in Slovakia.

2 Smart packaging

Conventional theories of packaging divide the main packaging functions into four elementary categories: protective, convenient, communicative and containing [9,10]. Innovative smart packaging is the output of original, unconventional and creative thinking except the usual structure of mind [9,11] leading to the production of interactive features of the packaging. Basically, there are distinguished two groups of such packaging systems:

- active packaging,
- intelligent packaging.

The traditional understanding of protection function of the packaging presents it as an inactive barrier between product and product´s environment. Regarding active packaging, the protective function of the packaging is focused on active protection of the product [9] that leads to extended shelf life or improved food safety while keeping the high quality of the food [12]. It can be obtained through smart package removal of negative impacts of environmental on food product quality [13]. Hopeful trend in wood processing industry is based on the smart packaging materials using incorporated antimicrobial agents [14]. Regarding the definition of active packaging materials we can divide them into groups following the way they influence the product´s characteristics. Absorbers are understood as active packaging systems based on absorption and emitters and active packaging systems are based on the substances release [15,16].

Intelligent packaging can be described as a packaging system which allows carrying out intelligent functions, e. g. to verify, detect, record, trace, communicate, and apply scientific logic. These functions make easier decision leading to extended shelf life, enhanced safety, improved quality, information, and finally it highlights potential problems [9].

By Kačeňák [12], the smart packaging is the term indicating systems aimed at monitoring conditions related to the product and thus providing information about the food quality - during transportation as well as storage. The smart packaging enables to recognize indicators of time-temperature, oxygen and carbon dioxide, temperature, pathogen and breakage [16]. The significance of smart packaging is especially related to considerable increase of importance of protective and information function of packaging.

Protective function of packaging is more important especially in active packaging which is obvious in its change from passive to the active product protection. Information function concerns smart packaging providing information about conditions of packing [17-20]. The smart packaging brings continuous information on the product condition. Packaging integrity is not the advantage just for the customer. It also enables to detect differences in the whole supply chain, from farmers to customers. It clearly results in reduction of food loss and waste and prevention of unnecessary transport and logistics. It presents more efficient as well as safer supply chain [21]. Basically, we can state that smart packaging is able to support better logistical handling and logistic costs decrease. Its other advantages are improved control of quality of packaging and contents, improved safety during use of packaging, improvements in production of packaging, improvement in re-use and recycling of packaging [22].

Previous studies described packaging as an essential needful part of the product; current studies point to its change to product´s wantable component [23,24]. However, packaging creates the first impression influencing the willingness to buy a product, therefore it should be functional as well as user-friendly. Moreover, it should be simple to use, provide substantial information and be suitable for storage [25]. Another important issue are consumers´ attitudes towards smart packaging that are different in various countries. Smart packaging materials are more popular and accepted by consumers in the US, Japan or Australia. On the other hand, they are not so popular and preferred in European countries [26]. This could be partially caused by differences in individual cultures or by lack of understanding of their advantages. Only a few products packed this way are offered in the market compared to the number of options mentioned in the literature, but it is likely these disproportions will be solved and smart packaging soon becomes generally available [27]. Over the last 20 years an important improvement in active packaging systems has been observed. Some packaging concepts that belong to this category have been used for a long time, but only in the last 20 years systematic research has been applied [13].

However, customers must be better informed about the intention and usage of a smart packaging system to obtain its wider use and higher acceptance by consumers. A report from Europe Active and Intelligent Packaging Market [28] shows that there has been a remarkable increase in this area and is assumed to increase to a great extent by the end of 2020 because of increasing demand for products with smart packaging. This fact is caused by changes in lifestyle and the request of manufacturers for longer shelf life.

Prasad & Kochhar [29] indicate that smart packaging offers a significant potential as a marketing tool. However, this type of packaging progress and introduction depends on the acceptance and effectiveness of cost for both industry and consumers.

This is the main reason why understanding of consumer attitudes towards the new generation of packaging is a necessary source of information for producers during marketing strategies making that are focused on new goods designs and their location on the market [30].

3 Methodology

To meet the given aim of the paper the Kano model was used. The model allows to determine customers' opinions regarding the requirements on the researched object. The method of identifying specific customer requirements is based on the elementary steps of the Kano model questionnaire [31], taking into account the dependence between the significance of the individual features of the chosen object, in this case smart packaging, and the satisfaction of the customer.

The research validity was defined by the methodology focusing on the calculation of respondents' sample [32]. It was given at a confidence level of 95%, a tolerance error of +/- 5% of the standard deviation of 0.5. At the given data it represents the value of 384.16, i.e., 385 respondents. The research was realized in September and December 2017 as well as the same time next year 2018 to identify the development of the innovation status according to the annual changes in the attitudes of respondents. There were asked 552 respondents. Regarding a confidence level, standard deviation, and margin of error we can consider the results to be relevant. The representative sample in terms of age was represented by 4 age categories equally: 15-26 years, 27-40 years, 41-60 years and 61 years and older. All determined age categories were equally represented.

Through interviews with experts in the given field, there were identified research attributes (parameters) for: the concept of intelligent and active packaging, their availability, awareness, functionality, voice performance, attractiveness of packaging, advertisement, freshness indicators and price.

The received responses to the positively and negatively asked question are evaluated according to the Kano cross rule to define the requirements for smart packaging as a research object, according to Ducár et al. [33] and Ullah & Tamaki [34] into Mandatory requirements (M), One-dimensional requirements (O), Attractive requirements (A), Reverse requirements (R), Irrelevant requirements (I) and Questionable requirements (Q).

The categorized customer requirements are stated in percentages. The highest percentage category defines the particular category of the researched attribute of packaging. Thereafter the innovation status is computed as the amount of points set to the individual identified categories of parameters examined in accordance with the above methodology, where M = weight 3, A = weight 2, O = weight 1, I = weight 0, R = -1 and Q = weight -2. The weights of the individual requirements were assigned according to the importance of the requirements of the Kano model [31]. Subsequently, the innovation status was calculated as the sum of the weights of the individual requirements and the impact of the factor size for every age category is calculated as the weighted average of each percentage of the resulting parameter of the specified customer requirements identified by the Kano model (the factor size is presented in positive values and therefore in the case of the influence of reverse requirements on its resulting value it is multiplied by -1).

The results for individual age categories are shown in the innovation perception typology matrix, which illustrates the impact of the studied innovation on individual age categories.

4 Result and discussion

Under the influence of global changes and improvement, considerable changes are apparent in the attitudes toward packaging materials. The changes are also on consumers' approaches to the product packaging and favourite functions. Innovative packaging is the output of original, unconventional and creative thinking extending beyond the ordinary thinking limits. In the paper we researched a perception of smart packaging as innovation, its availability, evaluation of its functionality and other requirements by using the Kano model, based on the assumption, that new products do not have equal success in the market [35]. Some products are accepted by consumers almost immediately whereas others need much time to get consumers' appreciation. Even a very successful innovation can end in failure because consumers are unaware of it [36].

The results of our research indicate that smart packaging has various impacts on consumers in different age categories (Table 1).

Table 1 The smart packaging perception in different age categories and the innovation status

Age / Parameters	15-26		27-40		41-60		61 and more	
	Requirements	Point	Requirements	Point	Requirements	Point	Requirements	Point
Concept of intelligent and active packaging	A	2	A	2	I	0	R	-1
Availability	I	0	I	0	I	0	I	0
Awareness	R	-1	I	0	R	-1	R	-1
Functionality	O	1	I	0	I	0	I	0
Voice performance	I	0	I	0	I	0	I	0
Attractiveness of packaging	I	0	I	0	I	0	I	0
Advertisement	I	0	I	0	I	0	I	0
Freshness indicators	Q	0	Q	0	Q	0	Q	0
Price	I	0	R	-1	I	0	R	-1
Innovation status*		**2**		**1**		**-1**		**-3**
Age / Parameters	**15-26**		**27-40**		**41-60**		**61 and more**	
Concept of intelligent and active packaging	30.02	2	38.5	2	37.63	0	36.97	-1
Availability	55.20	0	46.52	0	51.55	0	56.10	0
Awareness	50.24	-1	42.25	0	46.91	-1	46.67	-1
Functionality	27.32	1	60.97	0	59.79	0	61.82	0
Voice performance	51.14	0	58.29	0	55.15	0	57.58	0
Attractiveness of packaging	47.06	0	52.40	0	52.06	0	49.70	0
Advertisement	47.51	0	56.15	0	45.88	0	49.09	0
Freshness indicators	32.58	0	31.55	0	43.30	0	35.15	0
Price	52.94	0	43.32	-1	44.33	0	53.33	-1
Factor size*		**4.12**		**3.74**		**5.21**		**15.22**

**Innovation status is calculated as the sum of weights of the researched parameters*
Factor size is calculated as the weighted average of each percentage of the resulting parameter of the specified customer requirement identified by the Kano model (in the case of the negative value of the factor size, the result is multiplied by -1)

In Slovakia the consumers´ knowledge of smart innovations is still very low. Consumers do not positively evaluate its features. This fact is apparent in particular from the frequency of identified irrelevant (I), questionable (Q) and reverse (R) requirements by the Kano model (Table 1).

The positive perception and attitude to the concept of smart packaging is evident in the age category 15 to 26 and then 27 to 40 years. For these consumers smart packaging is attractive. On the contrary, these innovations are differently perceived by the elderly respondents. The age categories 41-60 and especially older respondents are specific by experiencing such innovation with negative satisfaction. With increasing age the innovation status shows a downward trend (Figure 1). The research results have clearly confirmed the theoretical basis noting consumers' fears of innovation, especially more in terms of technical innovations [37]. These findings are consistent with Loučanová et al. [17,38,39], O'Callaghan & Kerry [5] and Brook Lyndhurst Ltd. (2009 In [5]), Dopico [40] who consider older people to be more worried, less-positive and more likely they feel fewer advantages connected with smart packaging technologies.

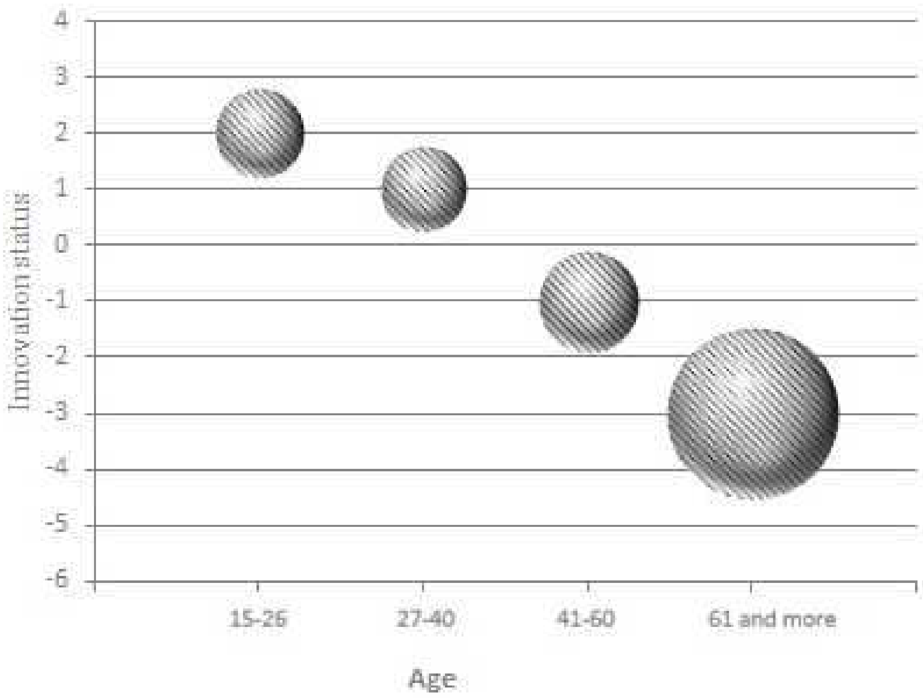

Figure 1 A typology matrix of smart packaging perception by respondents in Slovakia (2018)
Source: Research results

Nevertheless, the research results indicate low understanding of smart packaging, it is interesting to monitor the innovation status development according to the annual status change for the years 2017 and 2018 (Figure 2), indicating a significant change in the perception of this issue.

Continuously for the youngest monitored age category (15-26 years), smart and active packaging is still attractive. While retaining the innovation status at the same level, the impact of smart and active packaging has changed. It signifies the acceptance of this innovation by a still larger percentage of consumers in this age category. Constantly for this age group, this kind of innovative packaging is still attractive with clear positive impact on customers' satisfaction. The most important and interesting shift of innovation status is in the age category 27-40 years, representing a significant change from the previously negative to the positive innovation status. It means wider acceptance of that kind of innovation and positive improvement of consumers´ attitudes.

Nevertheless, the innovation status of smart packaging in the age category 41 years and older is still negative, a significant positive shift is seen mainly according to category 41-60 years, which means that a higher percentage of customers in this age category perceives them more positively. These changes indicate gradual learning and awareness about active and smart packaging issue also by elder people.

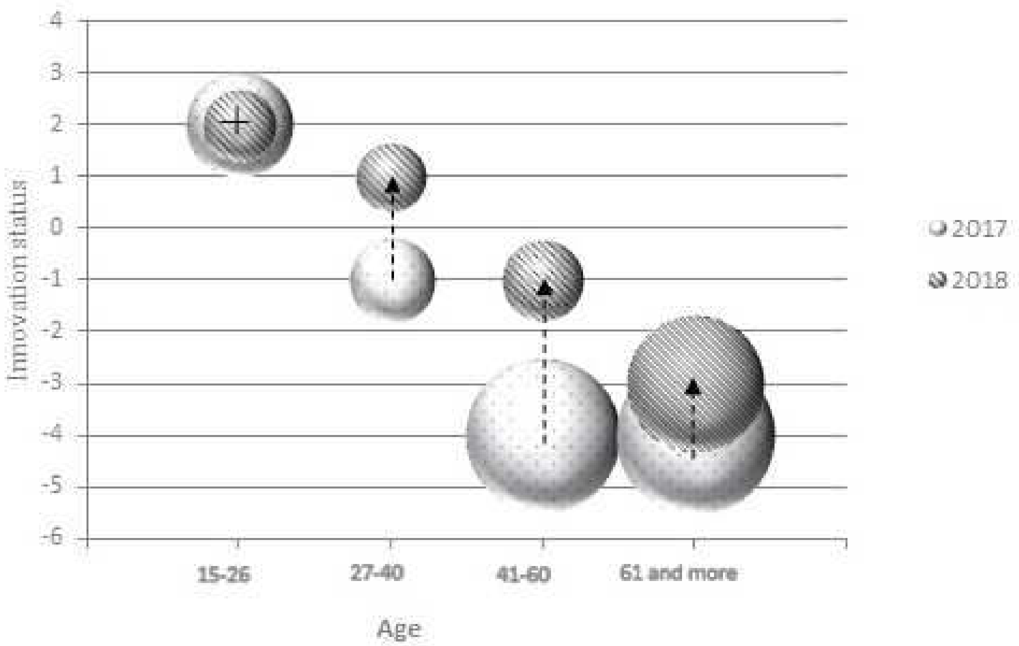

Figure 2 A typology matrix of smart packaging perception by Slovak respondents – the annual change 2017-2018
Source: Research results

The results comprehensively point to a positive shift in the evaluation of smart packaging by Slovak consumers. Therefore, it is very important to constantly inform and disseminate awareness of this issue, as increasing awareness of such innovations could ensure a more positive approach of the customers to the given innovations [41,42], because as Rogers [37] says, the customers are accepting the innovation when they feel no threat at all (it is in the case they are sufficiently informed) and, basically, that innovation will become a tradition. Also, according to Odeck & Bråthen [43], Frischer et al. [44] Parobek et al. [45], Straka [46,47] it is often the case people have a really negative attitude towards the innovations because the lack of proper information and clear explanation. This is the reason why companies must comprehend the customer's requests, preferences and attitudes and then to find the right way how to communicate with customers. The positive detection of the research is seen in a fact that respondents are interested in the concept of smart packaging, even in cases when they do not have any experiences with these specific products. This is the potential for demand for smart packaging in Slovakia. In the future, this support the development of products with smart packaging that can be considered as a smart system when it becomes part of an a control or feedback mechanism in relation to its usage environment (Improved logistical handling and reduction of logistic costs, control of quality of packaging and contents, improved safety during use of packaging, improvements in production of packaging and improvement in reuse and recycling of packaging) [22]. Effective operating on the market is not possible without innovation in the packaging within the integrated innovation process on the market as well as without suitably organized logistics. Suitably organized logistic chains represent increased chance to survive in the hypercompetitive environment through innovation. Based on the aforementioned information it is obvious that the basic role of smart packaging in the logistics is to arrange complex solutions of transportation processes in all aspects and mutual relations of the innovation packaging. It is also essential to keep consistency among the smart logistics, economy and business [48,49]. Benefits of smart packaging are clear. However, there are still questions that must be solved before packaging of this type spreads widely [27]. The issue of smart packaging is very attractive from the point of view of consumers and it makes them curious. Their interest can be used when creating the marketing strategy of products using smart packaging. We agree with the statement of Chukhray [35], that the accomplishment of innovation significantly depends on the ability to predict consumers' response to it.

5 Conclusion

Regarding the results we can state that the companies are interested in making packaging more innovative and creative. The selection of adequate packaging material is an extremely important task, too. In the future, smart packaging represents an opportunity to become a competitive advantage of products that are able to fulfil customers' needs and so to increase their satisfaction. Diffusing and managing of innovation certainly cannot exist without research of customers 'opinions because innovation acquiring is definitely an important factor for innovation success. In this paper we wanted to point out that consumer preferences and attitudes to the innovation in the form of smart packaging vary according to the factor age and knowing which packaging attributes and factors can determine consumer attitudes leads to better understanding of consumers and influencing behaviour towards innovation in the desired way. To conclude, we pointed out a positive shift in the opinions on smart packaging by Slovak consumers, what identifies with global trends (Stora Enso 2014 [50]; RISE – Sweden's Research Institute 2018 [51]) regarding a clear future demand for innovative packaging and a great need for smarter packaging.

The results also indicate the positive impact of smart packaging on Slovak customers, as the innovation status of smart packaging among Slovak customers in the given age categories has increased over the course of one year. Smart packaging is perceived as an attractive. Moreover, younger age category evaluates the functionality of smart packaging as an added value compared to the product perception as a concept.

This positive perception of the added value of smart packaging can be reflected in the technological development of block chain, which ensures product tracking and evaluation to make the whole logistic chain more effective within the development of innovation and eco-innovation.

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INFLUENCE OF THE PRICE MOVEMENTS TO THE ACCURACY WITHIN NUMERICAL PRICE FORECASTING

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Keywords: price forecasting, numerical modelling, exponential approximation

Abstract: The paper is aimed at commodity price forecasting using a numerical solution of the Cauchy initial problem for the 1st order ordinary differential equation. To acquire significant forecasting improvement, the idea of the modification of the initial condition value was realized. By having analysed the forecasting success of determined numerical models, it was found out that commodity price evolution affected the accuracy of the price forecasting. The absolute percentage prognoses errors were usually lower at a stable price increase and when price fluctuation appeared. Therefore, prognoses calculated without changing initial condition value were satisfying. Within significant changes in the price evolution and at a rapid price increase, the prognoses acquired higher absolute percentage errors. That caused replacing the initial condition value by the nearest stock exchange. Consider this strategy, the following calculated prognoses got closer to the forecast stock exchanges and price forecasting became more advantageous with respect to the price course.

1 Introduction

Mathematical modelling is one part of the commodity price forecasting and contributes to developing the new branches of solvability of these still current problems [1-4]. In mathematical models forecasting the prices on the commodity exchanges, the statistical methods are often used [5-11]. Our prognostic numerical models were based on the numerical solution of the Cauchy initial problem for the 1st order ordinary differential equations [12-15]. The monthly averages of the daily closing aluminium prices "Cash Seller & Settlement price" presented on the London Metal Exchange (LME) were worked on [16]. As can be seen in Figure 1, the price movements of the aluminium prices on LME (in US dollars per tonne) changed dramatically within the observing period [12-15].

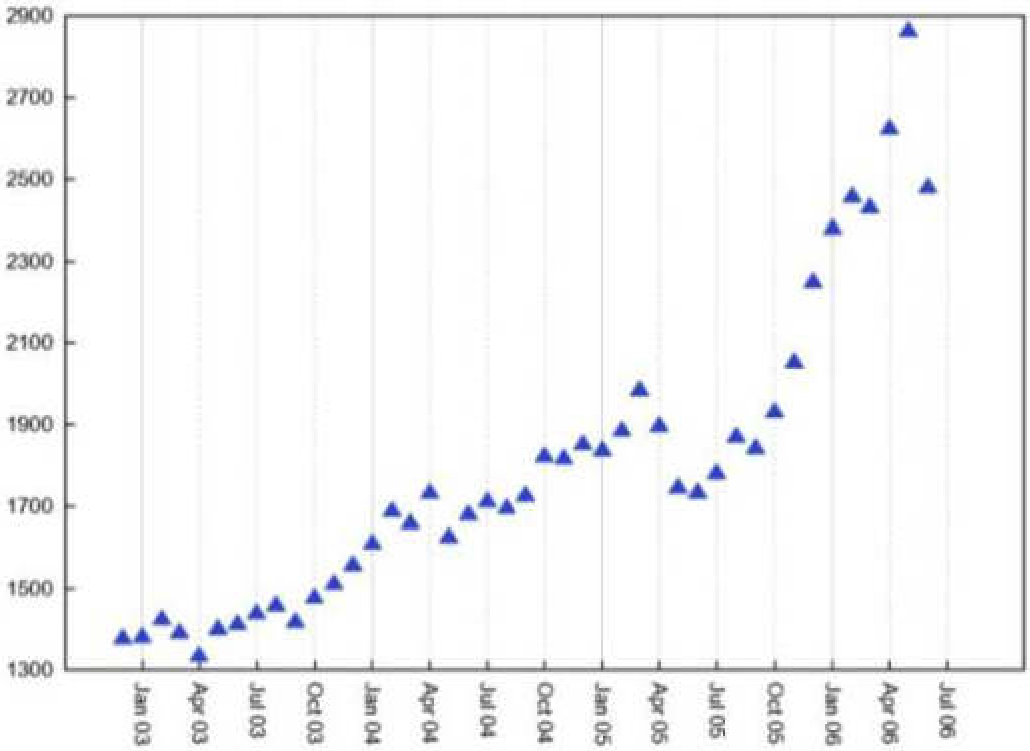

Figure 1 The aluminium stock exchanges on LME in the years 2003 – 2006 [12-15]

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2 Mathematical models

Let us consider the Cauchy initial problem in the form

$$y' = a_1 y, \quad y(x_0) = y_0 . \qquad (1)$$

The particular solution of the problem (1) is in the form $y = k\, e^{a_1 x}$, where $k = y_0\, e^{-a_1 x_0}$. The price prognoses were created by the following steps (more details in [12-15]):

The 1st step: Approximation of the values – the values of the approximation term were approximated by the least-squares method. The exponential function in the form $\tilde{y} = a_0 e^{a_1 x}$ was used. Let us consider two different variants, variant B and variant E (see Figure 2 and Figure 3).

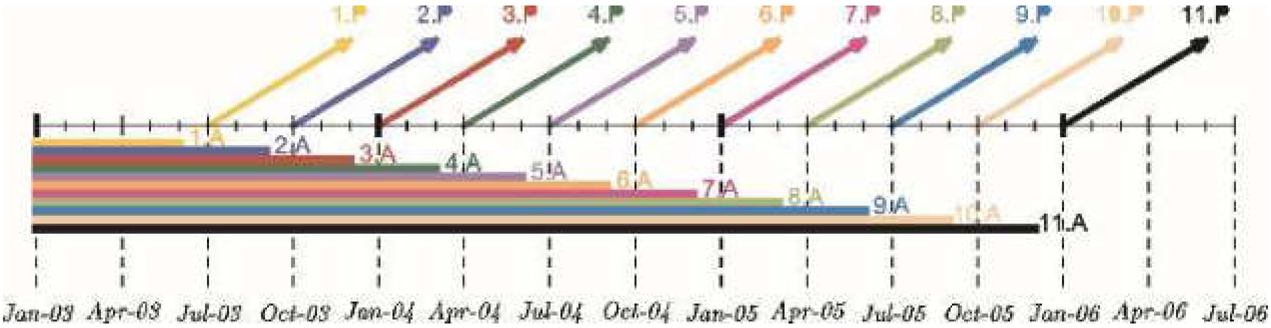

Figure 2 Variant B (A – approximation term, P – forecasting term) [12-15]

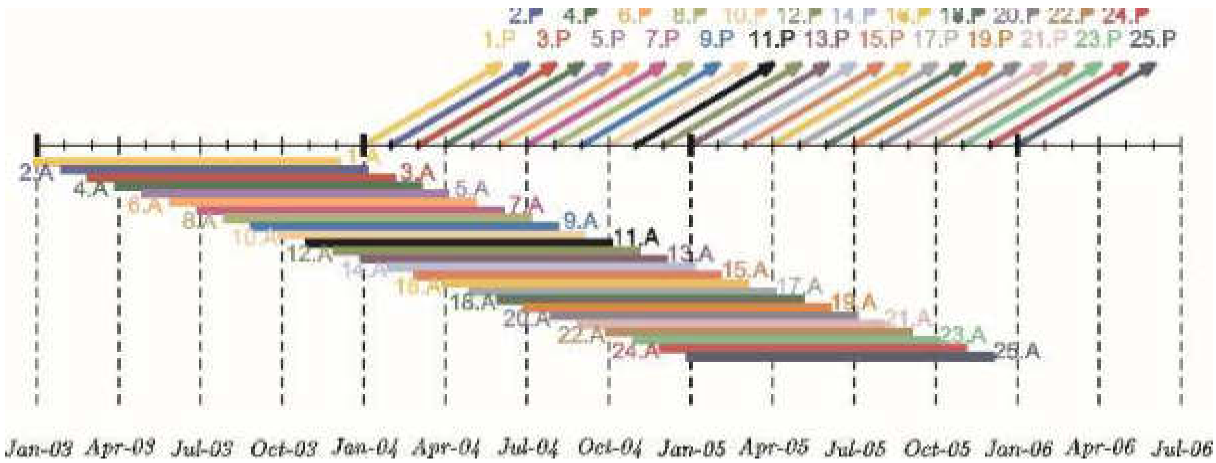

Figure 3 Variant E (A – approximation term, P – forecasting term) [12-15]

The 2nd step: Formulating the Cauchy initial problem – according to the acquired approximation function $\tilde{y}$, the Cauchy initial problem (1) was written in the form

$$y' = a_1 y, \quad y(x_i) = Y_i , \qquad (2)$$

where $x_i = i$ is the last month of the approximation term, Y_i is the stock exchange in the month x_i.

The 3rd step: Computing the prognoses – the formulated Cauchy initial problem (2) was solved by the numerical method [17]. The method uses the following numerical formulae

$$x_{i+1} = x_i + h ,$$

$$y_{i+1} = y_i + bh + Qe^{vx_i}\left(e^{vh} - 1\right),$$

for $i = 1, 2, 3, \dots$, where $h = x_{i+1} - x_i$ is the constant size step. The unknown coefficients are calculated by means of these formulae $v = \dfrac{f''(x_i, y_i)}{f'(x_i, y_i)}$,

$$Q = \frac{f'(x_i, y_i) - f''(x_i, y_i)}{(1-v)\, v^2 e^{vx_i}}, \quad b = f(x_i, y_i) - \frac{f'(x_i, y_i)}{v}.$$

The prognoses within six month following the end of the approximation term were determined. The daily prognoses in trading days were calculated by chosen numerical method. Their arithmetic mean served for finding the monthly prognosis in each month of the forecasting term (for more details see [12-15]). Let us determine the absolute percentage error [18], $|p_s| = \dfrac{|y_s - Y_s|}{Y_s} .100\,\%$, where y_s was calculated prognosis, and Y_s was the real stock exchange in the month x_s. The price prognosis y_s is acceptable in practice, if $|p_s| < 10\ \%$. Otherwise, it is named the critical forecasting value. To compare the accuracy of the forecasting of all forecasting terms, the mean absolute percentage error (MAPE) $\bar{p} = \frac{\sum_{s=1}^{t} |p_s|}{t}$ was determined [18], where, in our numerical prognostic models, $t = 6$.

Let us consider three different numerical models. Using the original model, the monthly prognoses in the months x_{i+s}, for $s = 1,2,\dots,6$, were obtained by solving Cauchy initial problem (2) without changing the initial condition value. Although the prognoses obtained by the original model were steeper increasing, the forecasting was not sufficient to accommodate to a steep stable increase or decrease. Also the changes in the price movements caused higher forecasting inaccuracies [15]. Therefore, we were interested in possibilities how to improve the forecasting results by modification of this model. The influence of the initial condition value's change to the forecasting accuracy was observed.

Consider the modified model, the initial condition value in the month x_{i+s}, for $s = 1,2,3,4,5$ was replaced by calculated monthly prognosis y_{i+s}. This strategy gave us similar results as the original model [15]. To improve the forecasting results, the idea of a replacing the initial condition value by aluminium stock exchange was realized. The initial condition value in the month x_{i+s}, $s = 1,2,3,4,5$, was changed either by the calculated monthly prognosis y_{i+s} or by the stock exchange in the month when the absolute percentage prognosis error exceeded the chosen 7 %. Let us named the modification of the initial condition value by the chosen stock exchange as the initial condition drift [12-15]. In the following figures, critical values are red. If the prognosis was not critical value, but its absolute percentage error was greater than 7 %, then that is blue. The prognoses with the absolute percentage error less than 7 % are black.

3 Result and discussion

3.1 The success of numerical models at commodity price forecasting

Within the considered 36 forecasting terms of variants B and E, the success of the determined models was studied. For each forecasting term, the most successful numerical model was defined [15]. The forecasting success of determined mathematical models within forecasting terms is visible in Table 1.

Table 1 The success rate of determined mathematical models

	The original model	The modified model	The model using initial condition drift
Variant B	5	1	6
Variant E	8	4	18
Total	13	5	24

The results show the forecasting by the model using initial condition drift as the most accurate, especially in variant E. This model acquired the lowest MAPE in 19 forecasting terms. In four of them, we obtained the same results by the model using initial condition drift and the modified model. The original model was the most suitable for 12 forecasting terms. In one forecasting term, forecasting results were the same for all chosen models.

Comparing the values of prognoses obtained by the original and the modified models, we have found out that the prognoses determined by the original model were faster changing than prognoses calculated in the modified model. Therefore prognoses of the original model were usually more accurate than prognoses of the modified model [15]. The differences between these two numerical models were too small. Within problematic forecasting terms, these models were such inaccurate that the initial condition drift occurred. The change of the initial condition value by the nearest stock exchanges got calculated prognoses closer to the real stock exchanges and significantly improved forecasting results [12-15].

Let analyze the forecasting success of determined models within different price evolution. The forecasting terms of variants B and E were divided into groups with the same type of the price course. Within these groups, the success of determined models were studied. For each forecasting term, the model with the lowest MAPE was found. The forecasting success of determined mathematical models is visible in Table 2 and Table 3.

Table 2 Distribution of the number of forecasting terms in groups of price movement - variant B

	The original model	The modified model	The model using initial condition drift
Stable price increase	2	0	1
Significant fluctuation	3	1	1
Price decline following the price increase	0	0	2
Price increase following the price decline	0	0	2

Table 3 Distribution of the number of forecasting terms in groups of price movement - variant E

	The original model	The modified model	The model using initial condition drift
Stable price increase	3	0	0
Significant fluctuation	4	3	5
Price decline following the price increase	1	1	6
Price increase following the price decline	0	0	7

The tables show that the model using initial condition drift was the most advantageous in both variants B and E when changes in the price course appeared. Within a price fluctuation, the initial condition drift was not always suitable. The most successful was model with the closest prognoses to the changing values of the stock exchanges. Steeply increasing prognoses of the original model were the most accurate within a stable price increase.

3.2 The forecasting success of the most accurate model

The model using initial condition drift was usually the most successful especially within significant changes in price evolution and at a steep price increase.

- **steep price decline following the price increase**

Within these periods, the price decrease was significant. The approximation terms with a price increase belonged to the observed forecasting terms. Therefore, the approximation functions and calculated prognoses were increasing too. Thus, forecasting by both the original and the modified models was not able to accommodate to a steep decline of the stock exchanges. The forecasting without changing the initial condition value by the stock exchange failed. The absolute percentage prognoses errors were higher and caused the initial condition drift [12,13].

Within the period *April 2005 – September 2005* (see [12] and Figure 4) the forecasting without using the initial condition drift failed. The prognosis in month with the highest decline (May 2005) was the most inaccurate. Because the absolute percentage prognosis error exceeded 7 %, the initial condition drift occurred. Using drift, the price decline was captured and a significant improvement in the forecasting was obtained. MAPE of the forecasting term obtained by the model using initial condition drift decreased from 12,55 % (the modified model) to 4,96 % (variant B) and from 12,63 % (the modified model) to 4,94 % (variant E). MAPE for the original model was 14,45 % (variant B) and 14,6 % (variant E) due to higher increased prognoses which were inappropriate when stock exchanges decreased.

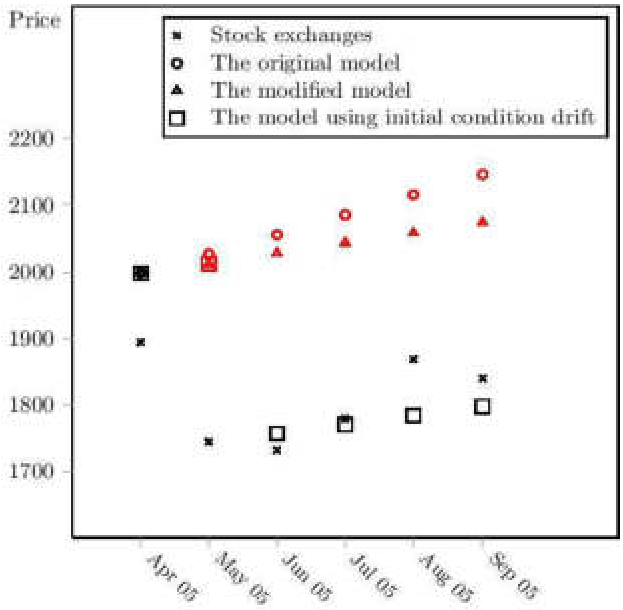

Figure 4 The forecasting by numerical models within April 2005 – September 2005 (variant E)

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- **steep price increase following the price decline**

Due to decreasing stock exhanges in the corresponding approximation terms, the approximation functions had either slowly increasing course or they could be even decreasing. Thus, the calculated prognoses at a steep increase were highly inaccurate. The initial condition drift was necessary for putting the prognoses nearer to a steep price increase [12,13].

Within the period *September 2005 – February 2006* (see Figure 5), the initial condition drift was occurred in the month with a steeper increase of the stock exchange (November 2005). By changing the initial condition value by the nearest stock exchange, the forecasting was able to accommodate to a steep price increase. The forecasting improvement caused decreasing MAPE of observed forecasting term from 12,55 % (the modified model) to 6 % (the model using initial condition drift) [10]. Using the original model, due to higher increase of prognoses, we obtained slightly better forecasting results than by the modified model (MAPE 12,48 %).

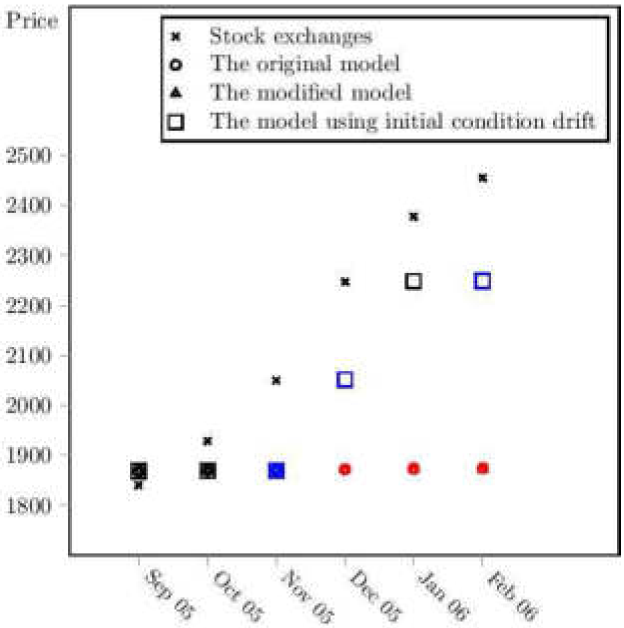

Figure 5 The forecasting by numerical models within September 2005 – February 2006 (variant E)

- **steep stable price increase**

If the price increase was steep, the increase of the forecast stock exchanges was higher than the increase of the stock exchanges within the approximation term. Therefore, the stock exchanges increased faster than calculated prognoses. Thus, the absolute percentage prognoses errors increased with time. If they exceeded 7 %, the ininial condition drift moved the next calculated prognoses closer to steeply increasing stock exchanges. That is a reason why the model using initial condition drift acquired the most accurate prognoses.

Within the period *October 2003 – March 2004* (see Figure 6), the forecasting failed in the third month of the period (December 2003). Using the initial condition drift, all critical forecasting values in the observed period were eliminated. The MAPE decreased from 9,44 % (the modified model) to 4,98 % (the model using initial condition drift) [12]. Larger values of the prognoses acquired by the original model improved forecasting results in comparison with the modified model. But, the increase of prognoses was not sufficient to catch steeply increasing stock exchanges. Thus MAPE of this forecasting term using the original model was 8,92 %.

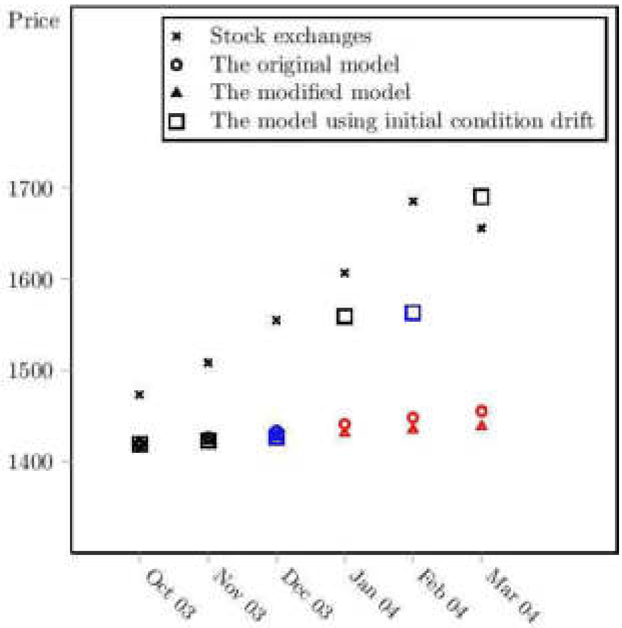

Figure 6 The forecasting by numerical models within October 2003 – March 2004 (variant B)

- **moderate fluctuation**

If moderate fluctuation occurred in forecasting terms, usually the absolute percentage prognoses errors were less than 7 %, so the initial condition value was not replaced by the stock exchange. Thus, forecasting results of both the modified model and the model using initial condition drift were the same [12,13]. In the case, the increased rate of forecast stock exchanges was slower than the increased rate of stock exchanges in approximation term, more suitable was a moderate increase of the prognoses acquired by the modified model than a higher increase of the prognoses obtained by the original model. This situation can be seen in period *April 2004 – September 2004* (see Figure 7), when the most successful were both the model using initial condition drift and the modified model (MAPE: variant B: 1,70 %, variant E: 2,51 %). MAPEs for the original model were 3,34 % in variant B and 4,90 % in variant E.

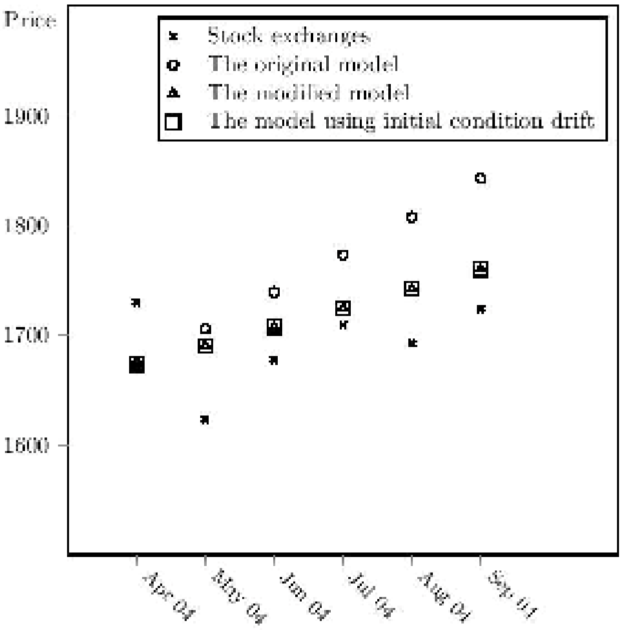

Figure 7 The forecasting by numerical models within April 2004 – September 2004 (variant E)

Nevertheless, the research results indicate low understanding of smart packaging, it is interesting to monitor the innovation status development according to the annual status change for the years 2017 and 2018 (Figure 2), indicating a significant change in the perception of this issue.

Continuously for the youngest monitored age category (15-26 years), smart and active packaging is still attractive. While retaining the innovation status at the same level, the impact of smart and active packaging has changed. It signifies the acceptance of this innovation by a still larger percentage of consumers in this age category. Constantly for this age group, this kind of innovative packaging is still attractive with clear positive impact on customers' satisfaction. The most important and interesting shift of innovation status is in the age category 27-40 years, representing a significant change from the previously negative to the positive innovation status. It means wider acceptance of that kind of innovation and positive improvement of consumers´ attitudes.

Nevertheless, the innovation status of smart packaging in the age category 41 years and older is still negative, a significant positive shift is seen mainly according to category 41-60 years, which means that a higher percentage of customers in this age category perceives them more positively. These changes indicate gradual learning and awareness about active and smart packaging issue also by elder people.

3.3 The forecasting success of the original model

Faster changing prognoses favoured the original model, especially in either a moderate stable or fluctuating price increase.

- **stable price increase**

At a stable moderate price increase, usually the absolute percentage prognoses error was less than 7 %, so the initial condition value was not replaced by the stock exchange. Thus, the forecasting results of the model using initial condition drift were the same as the results of the modified model [12,13]. Because of higher increase of the prognoses of the original model than the prognoses of the modified model, the forecasting by the original model was the most accurate.

This situation could be visible in the period *October 2004 – March 2005* (see Figure 8). The absolute percentage prognoses errors of the modified model were less than 7 %, so the strategy of the modification of the initial condition value by the stock exchange could not improve the forecasting results. MAPE of the forecasting term for the modified model and the model using initial condition drift was the same, 5,14 % in variant B and 5,30 % in variant E. The prognoses obtained by the original model increased faster, so for this model the lowest MAPE 3,63 % in variant B and 3,89 % in variant E was gained.

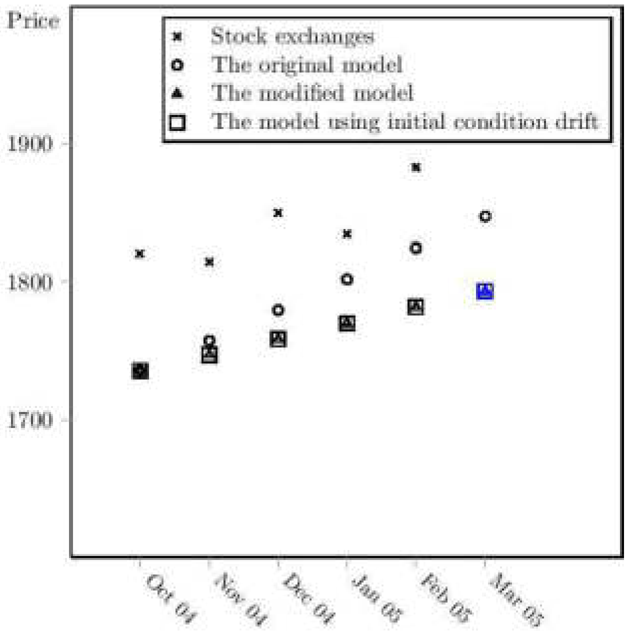

Figure 8 The forecasting by numerical models within October 2004 – March 2005 (variant E)

- **significant price fluctuation**

Within significant price fluctuation the most suitable were models that allowed placing the initial condition value the nearest to the following price evolution. By the model using initial condition drift, the initial condition value was often replaced by the local maximal or minimal value. That was usually not suitable for the forecasting of the following unstable price movements [12].

Within the period *January 2004 – June 2004* (see Figure 9) fluctuating increase was occurred. The forecast stock exchanges increased faster than the stock exchanges

INFLUENCE OF THE PRICE MOVEMENTS TO THE ACCURACY WITHIN NUMERICAL PRICE FORECASTING
Marcela Lascsáková

in the approximation term. Therefore the calculated prognoses were not enough accurate and the initial condition drift was realized. The initial condition value was changed by the stock exchange in the month with local maximal value (the fourth month, April 2004). Since the price increase did not continue, the calculated prognoses using the initial condition drift were the most inaccurate. MAPE of the forecasting term for this model was 5,40 % [12]. Better forecasting results were obtained without changing the initial condition value by the stock exchange. MAPE of the forecasting term was 3,72 % for the original model and 4,81 % for the modified model.

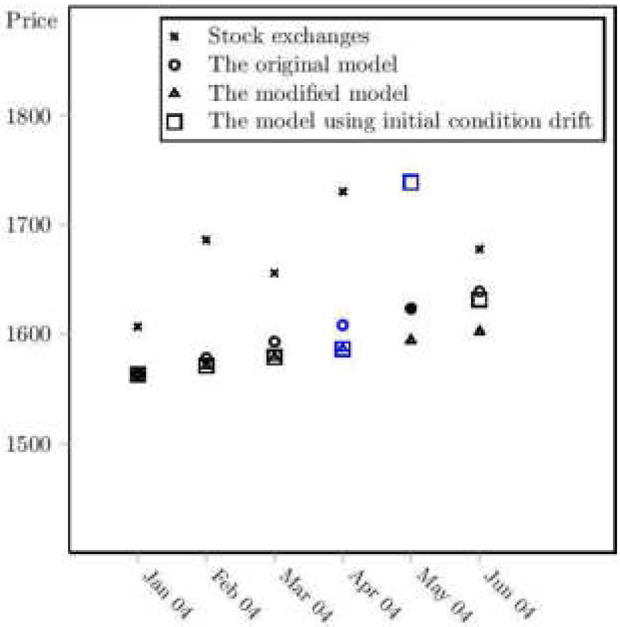

Figure 9 The forecasting by numerical models within January 2004 – June 2004 (variant E)

Within a moderate fluctuation increase in the period *June 2004 – November 2004* (Figure 10), the forecasting was so accurate that the absolute percentage prognoses errors were small and the initial condition value was not modified by the stock exchange. Therefore, higher increasing prognoses of the original model were more accurate than the same prognoses of both the modified model and the model using initial condition drift, which MAPE was 3,40 %. The most accurate was the original model with MAPE 1,59 %.

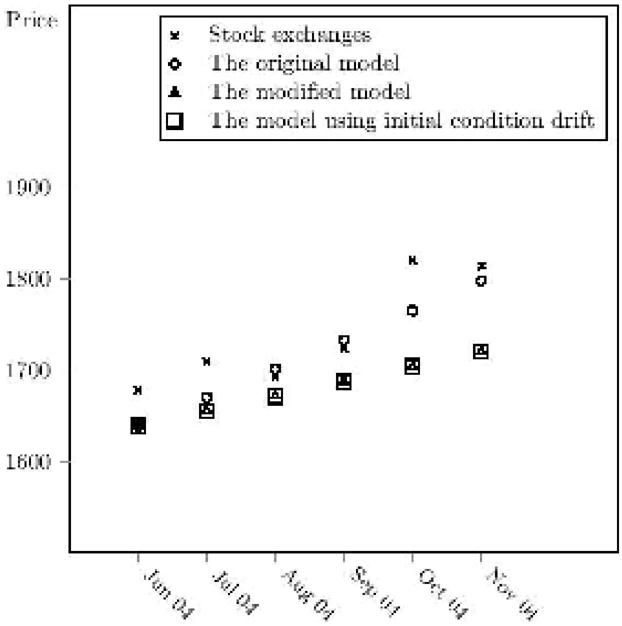

Figure 10 The forecasting by numerical models within June 2004 – November 2004 (variant E)

4 Conclusion

By having analyzed the forecasting reasults of determined numerical models, it was found out that price evolution influenced the forecasting accuracy of the models. Within the most problematic forecasting periods, the model using initial condition drift was usually the most advantageous. We recommend to use this model, especially during significant changes in the price evolution and at a steeper price increase. The idea of the modification of the initial condition value by the stock exchange during the numerical solution of the determined Cauchy initial problem, significantly improved the forecasting accuracy. That allowed to put calculated prognoses closer to the real price movements and made the forecasting more accurate than the forecasting by either the original model or the modified model. Within price fluctuations, due to replacing the initial condition value either by the local maximal or local minimal stock exchange, the initial condition drift was not always advantageous. Also, when the initial condition drift did not occur, higher increased prognoses of the original model were more advantageous than the prognoses determined by the modified model. Using the most appropriate type of the mathematical models within different price evolution made price forecasting more accurate.

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TECHNOLOGY DEVELOPMENT PROCESS AND MANAGING UNCERTAINTIES WITH SUSTAINABLE COMPETITIVE ADVANTAGE APPROACH

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Keywords: Sustainable Competitive Advantage (SCA), SCA risk level, knowledge and technology effect, manufacture strategy index, product and process development cycle

Abstract: The main purpose of this research work is to assist the decision-making process which is related to technology and knowledge factor within an organization. The data has been gathered and analysed from a particular multinational company that operates in the ceramic manufacturing industry within Malaysia. Four respondents were sought to answer the sense-and-respond questionnaire, including the part on technology sharing. The priority among technology types, including basic, core, and spearhead was decided by the maximum coefficient of the variance. The work has two main contributions: 1. It proposes and validates a tool for decisions and strategies related to technology focus in firms, and 2. expands the notion of technology types from focusing only on product development to one that focuses on both product and process development. The results of the study show that the proposed model which was previously applied in high tech start-ups and local medium-size enterprises is applicable in large industries involved in mass production.

1 Introduction

It is generally acknowledged that nothing is constant, especially in the competitive business environment, except for change. As such, change creates turbulence and uncertainty, along with affecting the respective dynamics and balances involved in any particular process. Complexity increases the danger of making wrong judgments in today's business world [1]. For instance, changes in Manoeuvring Characteristics Augmentation System (MCAS) software that was misaligned with Boeing's 737 MAX sensor caused the entire fleet of 737s to be grounded internationally. These sparks global turbulence in the aviation industry, especially after two of the aforementioned aircrafts crashed. Turbulence thus leads to a shorter product life cycle (PLC), and thus emphasizes the importance of sustaining a competitive advantage in the overall business environment. Indeed, the real goal of any business endeavour is to attain SCA, instead of momentary business advantages. One approach to gauge and attain SCA is via the Resource-Based View (RBV) approach. Through RBV, firms are treated or seen differently, even though they are competing within a similar industry. This perspective is indeed valid and acceptable because, in the RBV, firms are viewed from their respective internal resources. There are few methods to assess and analyse SCA in business environments, such as the Critical Factor Index (CFIs), Sense-and-Response (S&R) method, and manufacturing business strategy.

Ranta and Takala introduced CFIs in 2007 for manufacturing managers to make decisions on allocating and/or reducing critical resources necessary to their respective business processes that were affected [2]. CFI allows decision-makers to sense which business attributes require their response and actions, and this is derived from the experiences and expectations of the firm's employees,

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business associates, and customers. Methodologically, the CFI later evolved and redeveloped into the BCFI and so on. This article introduces the grounding theory and its respective literature of SCA and related findings onto the case study of a ceramic manufacturing firm. Subsequently, the discussion and conclusion based on the research's results will also be presented.

2 Theory background

2.1 *Competitive advantage*

Competitive strategy means being different and having a unique niche within the business environment. Explicitly, "it means choosing a different set of activities to deliver unique value" [3]. In today's' business world, a company can win over its competitors if it can create marketable differences and manage to preserve them. Based on Miles and Snow typology, there are four strategic positions in which a company should consider taking: Prospector, Analyser, Defender, and Reactor [4]. Once a strategic position of the company is set, all the activities and processes should be built upon and aligned with that. Specifically, the concept of sustainable competitive advantage is based on 1. Finding a unique competitive position for the company, 2. Tailoring activities and processes based on the strategy, 3. Making trade-offs, 4. Fitting across activities, 5. Attaining operational effectiveness. In terms of strategy and sustainable competitive advantages, there are occasions where managers just emulate what their competitors have successfully developed. As such, they might chase each new technology without evaluating its suitability with their main strategy. Although both external and internal factors affect company positions in the markets and its profitability, it is often the case that internal factors are extremely important [3]. Based on the resource-based view (RBV), whatever a company needs to succeed in terms of its resources should exist within the firm. Therefore, the main challenge of a company is how to use its limited resources and angle its process towards gaining competitive advantage [5].

2.2 *Technology as a source of competitive advantage*

Technology is one of the main drivers of competition. It can change the structure of an industry, create new business opportunities or eliminate businesses. Despite the importance of technology, it should be emphasized that technology is not important for its own sake. Technology is important if it helps firms to reduce costs, create differentiation, and improve the quality of their products. Technology is embodied in every value activity and everything a firm does, involves some sort of technology [6]. Therefore, technology can have a powerful effect on both cost and differentiation. If a firm can discover better technology for performing a process better than other competitors, it can gain a competitive advantage [7].
Abernathy and Utterback (1987) studied the concept of technology in manufacturing and suggested that there are two paths for technology in any organisation, namely product technology and process technology [8]. The development of technology starts with the development of products (product technology), and when it succeeds in making differentiation or increasing quality, the development in the process (process technology) begins to reduce the cost with economies of scale. This is illustrated in Figure 1.

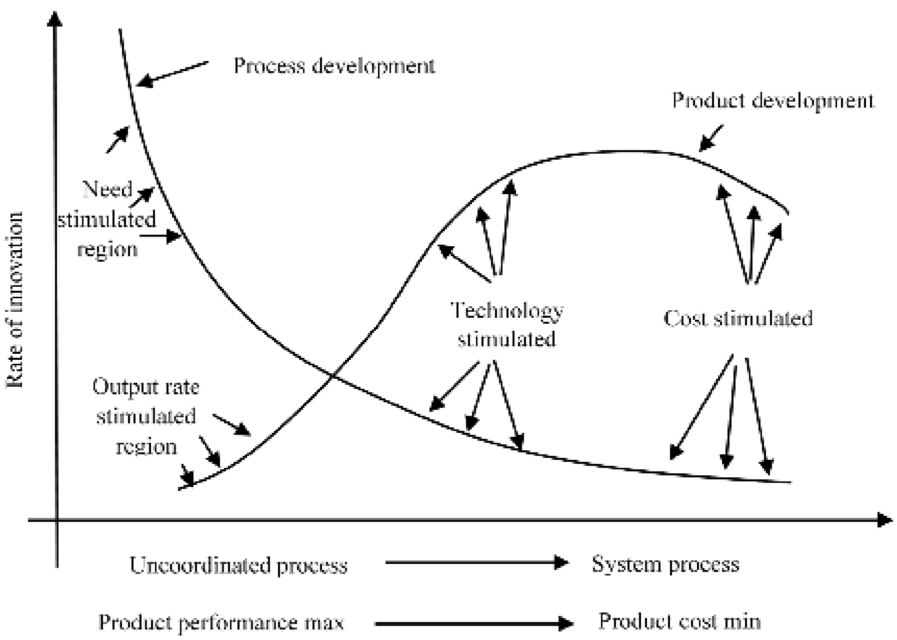

Figure 1 Two paths of technology development: process and product [9]

Tuominen, Knuuttila, and Takala (2003) studied the development of technology regarding the product life cycle and proposed three types of technology: Basic, Core, Spear-head technology [10]. The relationship between these three types of technology and the product life cycle is demonstrated in Figure 2.

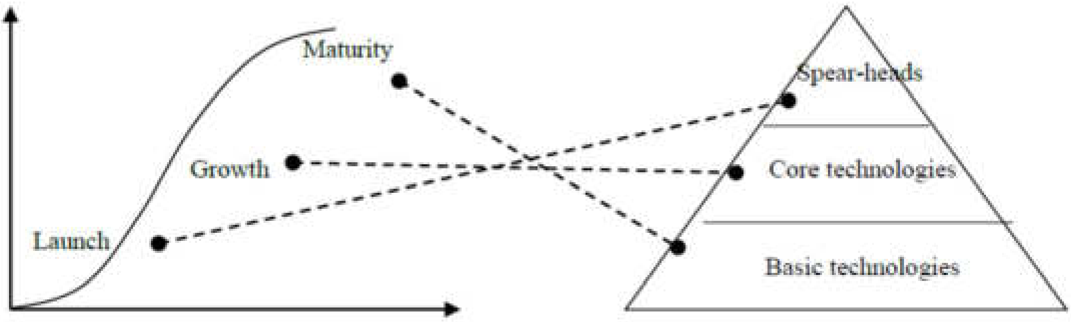

Figure 2 Different technology through product life cycle [10]

Product development starts with spear-head technology. This kind of technology helps a company to differentiate itself in the future and gain a competitive advantage. In the particular ceramic tile manufacturing firm used for this case study, spear-head technology included automated kiln (baking processes) and conveyor-based automatic movement (including sensors). The core technology is the kind of technology that got approved in product development and brought a competitive advantage to the firm in the current situation. Indeed, core technology is the previous spear-head technology which has also developed the process in such a way it is suitable for the economy of scale and yet is cost-effective. In this case, the core technology would be the press-moulding process and its moisture-sensitive controlling mechanism. Finally, basic technology is related to mature technology which might have less cost/benefit trade-off in improving, and sometimes the firm outsources basic technology to focus on core and spear-head technology development. In this manufacturing firm, basic technology includes raw-material control/selection mechanism, painting processes, and packaging operation.

Considering the Tuominen et al., (2003) work, we can draw a more comprehensive picture of the different technologies through the process and product technology development [10], as depicted in Figure 3.

3 Literature gap

A focus on technology and decision about technology investment is a fundamental problem that is faced by the management field. By making the right choices in the technology to invest in and following correct technology strategies, firms can gain and sustain competitive advantage which guarantees their success in the market. Takala, Leskinen, Sivusuo, Hirvelä, and Kekäle (2006) proposed a sand cone model to prioritize different strategy focus, including knowledge and technology, in the Finnish air force [11]. This model was also applied to determine the strategy and knowledge focus of the Finnish ice hockey team [12]. Later on, the sand cone model was also applied to knowledge management strategy in a Malaysian university library [13]. Coccia (2017) developed a framework of technology choices during its evolution in an organization and sought to answer the question of when to apply radical development in technology and when it is suitable to use incremental innovation in technology [14].

There are some researches which follow Barney and Wernerfelt, considers the firms' limited resources, and tries to prioritize the technology and knowledge need of the firm based on the main strategies of the companies in such a way that resource allocation for all the different activities is balanced [15,16]. The main idea behind these research works is to find that type of technology (basic, core, spearhead) which causes the highest amount of uncertainties in the firm and to invest in it to reduce risk and sustain a competitive advantage. In the study by Takala, Zucchetti, Daneshpour, Kunttu, Välisalo, Pirttimäki and Kiiski (2016), the concept of different types of technology (spear-head, basic, and core) is used within the sand cone model, with the authors using the maximum coefficient of variance to decide which types of technology causes the highest amount of uncertainty among different departments [17]. This work built upon the previous works and tried to apply both the RBV and sand cone models in establishing technology requirements. The research was based on this particular assumption that the main source of risk and uncertainty was due to the difference in the attitude of decision-makers in dealing with the subject [18]. Moreover, this research sought to expand the notion of technology in both the product and process development phase. Finally, the proposed mothed is applied in a multinational conventional company for the first time while the previous works focus on technology-based start-ups and local industries.

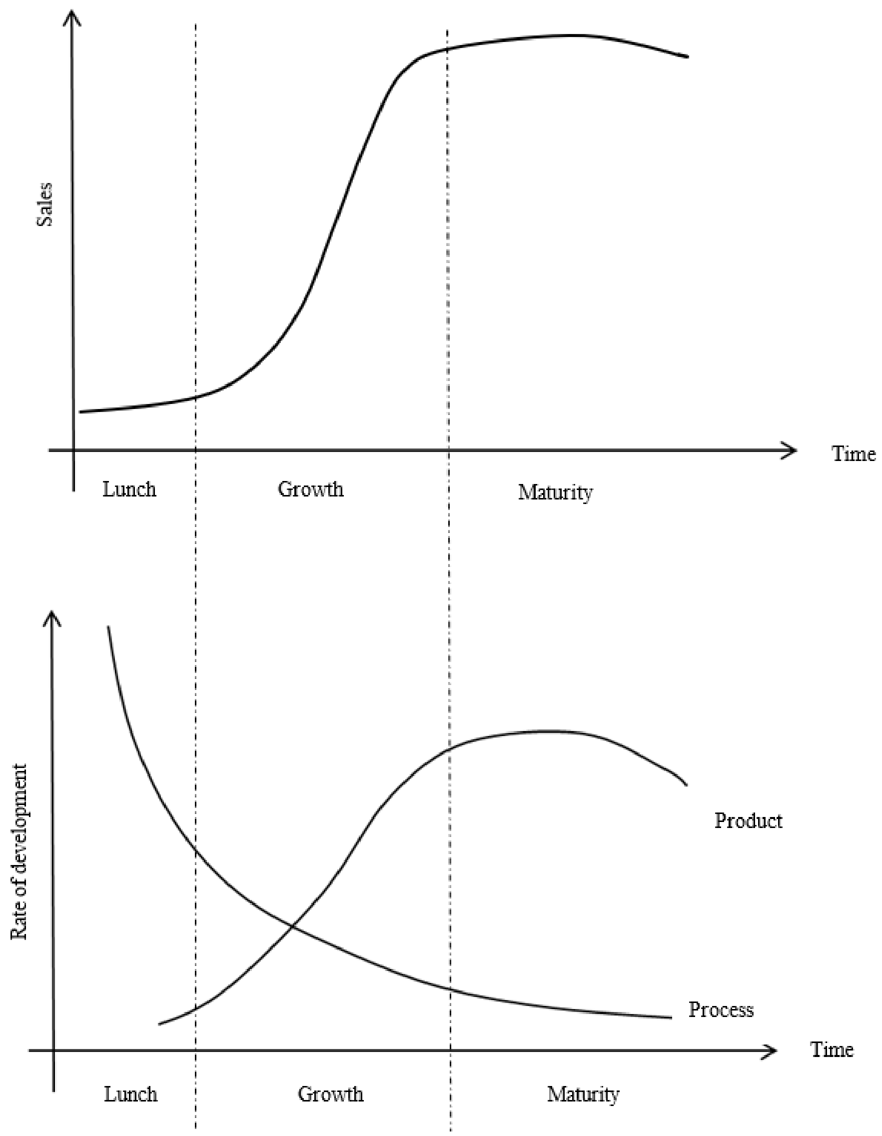

Figure 3 Different technology all over product and process development

4 Method

This research applies the sense and respond questionnaire, a method introduced by Ranta and Takala [2]. The sample of this questionnaire is presented in Table 1. Having filled this questionnaire, respondents evaluate their expectations and experiences regarding each attribute. Also, they are able to compare themselves with competitors and determine the development of each criterion within a specific time frame.

Table 1 Format of sense and respond questionnaire.

Performance attribute	Scale: 1=low, 10=high		Compared with competitors			Direction of development		
	Expectation (1-1)	Experience (1-10)	worse	same	better	worse	same	better
Performance 1								
Performance 2								

In order to integrate sense and respond questionnaire to Miles and Snow topology (which is one of the most popular business strategy classifications), each attribute above is assigned to the component of the RAL model [19] based on the RAL model, prioritizing among quality, cost, time and flexibility is directly related to responsiveness, agility, and leanness [2]. This relationship is demonstrated in Figure 4.

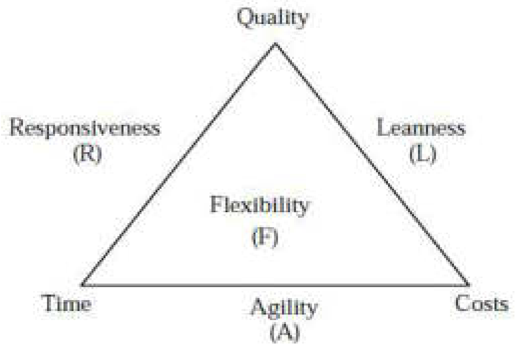

Figure. 4. RAL model [20]

Table 2 presents attributes which are used in this study. It also presents their assignment to the RAL model components.

Table2. Detail attributes of the sense and respond questionnaire

	ATTRIBUTES	
	Knowledge & Technology Management	
1	Training and development of the company's personnel	← Flexibility
2	Innovativeness and performance of research and development	← Cost
3	Communication between different departments and hierarchy levels	← Time
4	Adaptation to knowledge and technology	← Flexibility
5	Knowledge and technology diffusion	← Cost
6	Design and planning of the processes and products	← Time
	Processes & Workflows	
7	Short and prompt lead-times in the order-fulfilment process	← Flexibility
8	Reduction of unprofitable time in processes	← Cost
9	On-time deliveries to customer	← Quality
10	Control and optimization of all types of inventories	← Quality
11	The adaptiveness of changes in demands and in order backlog	← Flexibility
	Organizational systems	
12	Leadership and management systems of the company	← Cost
13	Quality control of products, processes and operations	← Quality
14	Well defined responsibilities and tasks for each operation	← Flexibility
15	Utilizing different types of organizing systems	← Flexibility
16	Code of conduct and security of data and information	← Cost
	Information systems	
17	Information systems support the business processes	← Time
18	Visibility of information in information systems	← Time
19	Availability of information in information systems	← Time
20	Quality & reliability of the information in information systems	← Quality
21	Usability and functionality of information systems	← Quality

Additionally, respondents are requested to evaluate each of the attributes above in terms of the percentage share of technology. They should also determine the share of basic, core, spear-head technology in detail so that all the attributes combine into a sum totalling 100%. The idea behind this corresponds to Porter's point of view, which is that everything a firm does shall incorporate some sort of technology [7].

Once the questionnaire is filled, the next step is to find which technology type causes the biggest amount of disagreement among respondents for each attribute. To find the source of disagreement and uncertainties, variability coefficient regarding each technology is calculated as follow:

$$Coef.Var_{Basic} = \frac{Standard\ Deviation_{Basic}}{Average_{Basic}} \quad (1)$$

$$Coef.Var_{Core} = \frac{Standard\ Deviation_{Core}}{Average_{Core}} \quad (2)$$

$$Coef.Var_{Spear\ Head} = \frac{Standard\ Deviation_{Spear\ Head}}{Average_{Spear\ Head}} \quad (3)$$

In order to evaluate the risk level associated with each type of technology regarding RAL model components, formula 4 is used:

$$c_1: Quality\,, c_2: Time, c_3: Cost, c_4: Flexibility$$

$$\left\{\begin{array}{l} Total\ \underset{c_1,c_2,c_3,c_4}{TK\ risk}\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\left(\sum_{b_1,c_1,sh} Coef.Var_i\right)^2\right]^2} \\ Partial \left\{\begin{array}{l} \underset{c_1,c_2,c_3,c_4}{TK\ risk\ Basic}\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\sum_b\left(\frac{std_i}{mean_i}\right)^2\right]^2} \\ \underset{c_1,c_2,c_3,c_4}{TK\ risk\ Core}\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\sum_{core}\left(\frac{std_i}{mean_i}\right)^2\right]^2} \\ \underset{c_1,c_2,c_3,c_4}{TK\ risk\ Sh}\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\sum_{sh}\left(\frac{std_i}{mean_i}\right)^2\right]^2} \end{array}\right. \end{array}\right. \quad (4)$$

In the formula above, the $Coef.Var_i$ for different types of technology is calculated by formula 1-3. In order to evaluate how the strategy related to knowledge and technology is sustainable, the following formulas are used:

$$Total\ Risk(Geom) = [(1 - SCA)TKrisk]^{\frac{1}{2}} \quad (5)$$

$$Total\ SCA\ risk\ level = 1 - Total\ Risk(Geom) \quad (6)$$

In formula 5, SCA stands for the sustainable competitive advantage of a firm without considering the technology and knowledge.

5 Results

The results of the study show that the resource of the ceramic manufacturing firm is correspondingly allocated among different tasks. Resource allocation based on the Balanced Critical Factor Index (BCFI) is presented in the following bar chart.

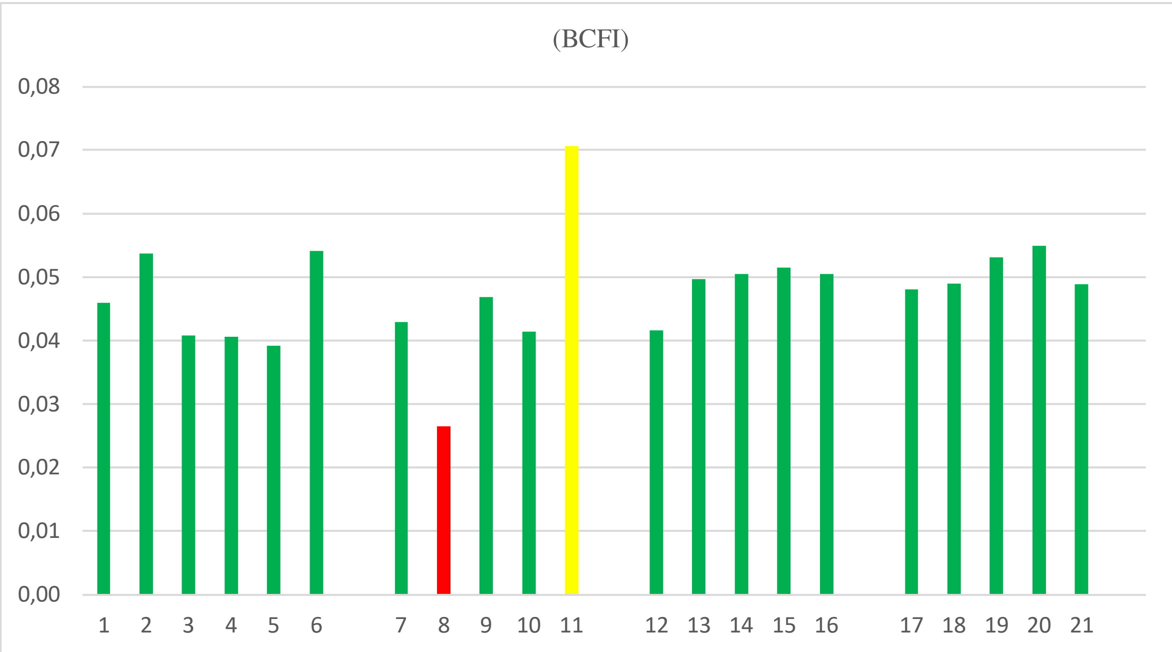

Figure 5 Resource allocation of the company based on the BCFI

As Figure 5 illustrates, only the attribute “Reduction of unprofitable time in processes” is under-resourced and the “Adaptiveness of changes in demands and in order backlog” is an over-resourced attribute. In terms of strategy position, the manufacturing firm is an analyser type, which is based on Miles and Snow typology [21]. The manufacture strategy indices are presented in Table 3 and Figure 6.

Table 3 The manufacturing firm’s business strategy indices

PROSPECTOR	ANALYSER	DEFENDER	REACTOR
0.89	1.00	0.90	0.89

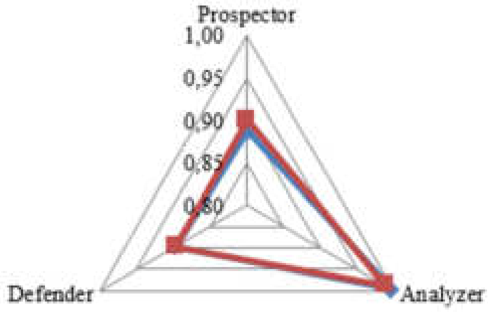

Figure 6 Company business strategy based on Miles and Snow typology

The percentage share of different technology for different attributes are presented in Figure 7.

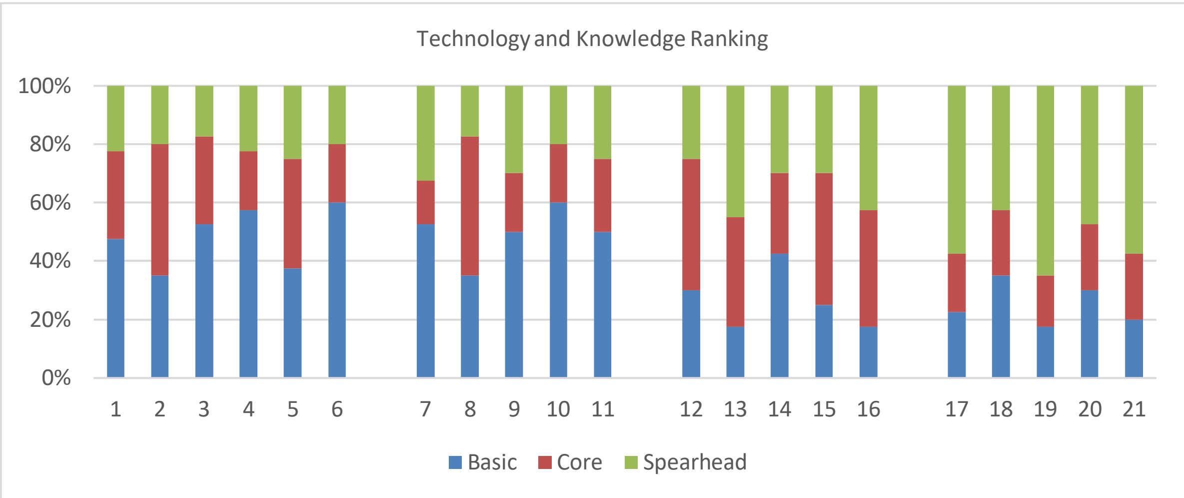

Figure 7 Percentage partition technology share for different attributes

As Figure 7 demonstrates, one technology is not the most dominant one for all the attributes. For example, spear-head technology is the dominant technology for activities related to information systems while basic technology and core technology correspond with dominance in activities related to "knowledge and technology management" and "organizational system", respectively.

The coefficient of variance and risk related to each type of technology is calculated based on formulas 1 to 6 and the results are presented in Figure 8.

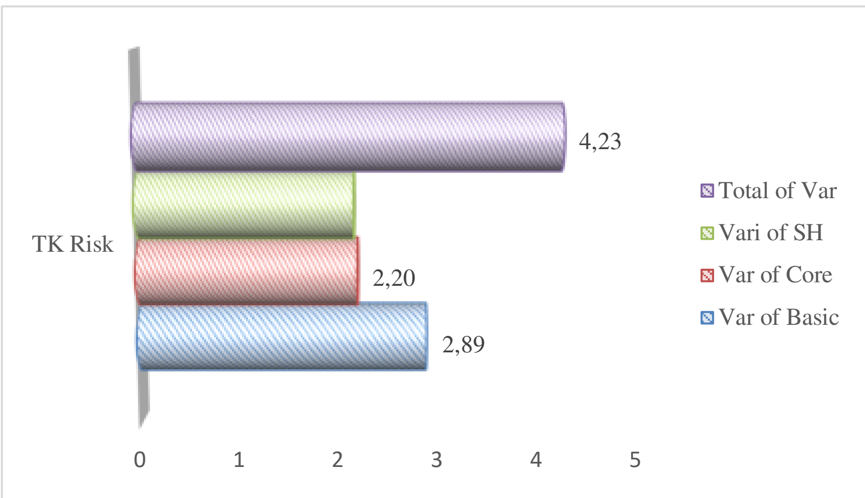

Figure 8 The uncertainties related to different technology and overall variance perspective

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As depicted in Figure 8, basic technology is the main source of risk and uncertainties in the ceramic manufacturing firm. Considering the development of technology in terms of process and product, dominating basic technology shows that the firm should invest more in process development rather than product development. In strategic move and initiative, the firm should invest more in developing manufacturing processes, including automation, and at the same time, look towards reducing the overall operational cost.

Figure 9 presents the impact of technology and knowledge policy in gaining a sustainable competitive advantage for the manufacturing firm. As is presented in figure 9, and taking into consideration the knowledge and technology perspectives, the firm resource allocation and policy is significantly less sustainable compared to the situation in which technology and knowledge factor are excluded.

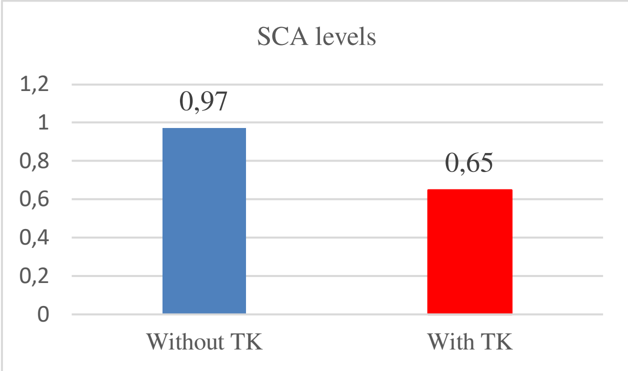

Figure 9 The effect of technology and knowledge factor on the level of SCA

Specifically, the comparison of the total SCA considering knowledge, technology, and sustainability regarding each type of technology is presented in Figure 10. The figure also shows that the decision regarding basic technology is less sustainable as compared to other types of technology.

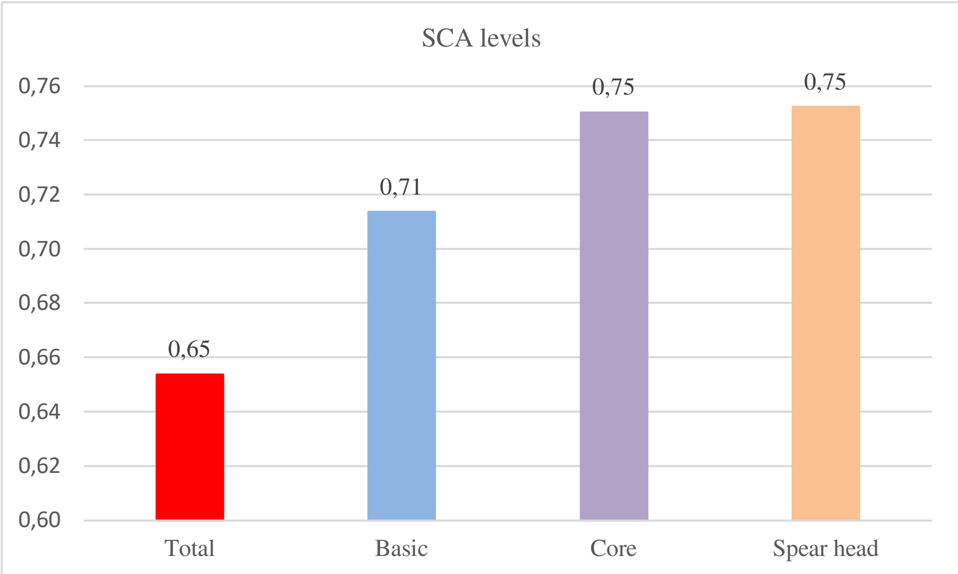

Figure 10 The SCA level with technology and knowledge factor, total and partial

6 Discussion

This research contributes to the field in two main subjects:

1. Developing a tool for technology and knowledge decision-making activities. In this regard, this work is built upon previous works that propose a method to prioritize technology investment and validate it in high-tech start-ups [22]. What is new here is that the proposed model is applied to a multinational large-size firm in a more conventional industry and the obtained results proved that the model is applicable both in general and in a conventional manufacturing industry.
2. The work contributes to current literature related to process and product development phases in the firm. Previous works made a connection only between technology types and product development. However, this work expanded the concept further and related technology types to both product and process development. Based on the current literature, innovation and development in the firms begin with the product. Tasmin and Woods (2007) advocate that product innovation is strongly related to the effective management of a firm's knowledge, process, technology, and its niche market [23]. Once a firm produces a product that can differentiate itself from others, the next stage would be to develop the relevant processes in such a way that producing the new product could also be made economical. The initial phase of product development, which is called the launching phase, is

closely incorporated with spearhead technology. At this stage, the cost of producing a product is extremely high, with the firm generally having an internal plan to apply it in the future and reduce its cost. In the phase of growth, the ability of new products in making differentiations is proven and the process is optimized in such a way that producing the new product on a large scale is economical. This condition where both product and process development are at the optimal level is related to the core technology. The growth stage of product development is followed by a maturing phase in which neither the product nor the process has the capacity to develop further and the company should reduce the cost of producing its products as much as possible, with a focus on newly invented product and through innovated technology in order to sustain its position in the market. The last phase is very much related to the existing basic technology. This research corresponds to the different types of technology which is embedded in the initial process and product development phase. The domination of basic technology in the studied firm in this research suggests that the firm should focus on the development of this current process rather than developing new products to sustain its position and competitiveness in the market. This result corresponds to the situation of the attribute “reduction of unprofitable time in processes” being an under-resourced attribute. This attribute also belongs to the “Cost” component of the RAL model. Therefore, investing this criterion, and related issues such as better control of work-in-progress, will ultimately reduce costs.

7 Conclusion

Business strategy as a comprehensive plan that integrates a firm’s major goals and action plans, positioning it as an essential role in a firm’s success. The role of business strategy is more important in today’s business world because of rapid change and the turbulent environment in the global business landscape. The concept of technology and the decision related to that is very important because the level of automation in industry is increasing rapidly, particularly with the introduction of new technologies and robots [24]. Since the mid-1990’s, sense and respond point of view has replaced traditional “make and buy” attitude in the business world and enabled firms to sense market changes in a timely manner and respond to those changes quicker [25]. Since the introduction of sense and respond philosophy, different research works have been conducted to integrate Miles and Snow typology and to constitute different drivers of competition. The latest effort was to consider technology and knowledge factor in the sense and respond questionnaire and try to propose a method that assists technology and knowledge decision making processes in the organization. This research work was built upon previous works and considers three types of technology in an organization: basic, core, and spearhead, and tries to show which kind of technology is worth investing in, based on firms' overall strategy and resource allocation. The method which is proposed here is based on the sand cone concept and uses the maximum coefficient of variance of each technology type to prioritize different technologies. The data has been gathered from a big multinational company in the industry of ceramic tile manufacturing, and the results of this study show that this method, which was previously tested in high tech start-ups, could also be implemented in other industries as well. From a practical point of view, the paper tries to present and validate a tool that could constitute technology in company business strategy. This tool could fulfil the communication gap between the operational manager who has main knowledge regarding the technology requirement, and the business manager who is the main person responsible for setting firm business strategy. However, the author suggests the implication of proposed tools in other industries and the inclusion of a bigger number of respondents as well. Another direction of future work would be to conduct a case study and implement the proposed tool among the two different samples of a business: top managers and operational managers, in order to see how much their point of view differs.

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USE OF DIGITAL TOOLS IN LOGISTIC AND PRODUCTION FACILITY MANAGEMENT FOR EFFECTIVE INFORMATION FLOW

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Keywords: data, data collection, digital forms, information flow, paperless
Abstract: The article deals with the use of digital forms in the manufacturing environment to reduce the amount of printed paper and streamline the flow of information of production and logistic processes. The aim of this article is to point out the possibility of using simple and commonly available solutions to collect the necessary data. The problem is the need for higher computer skills of ordinary users. It can be used in both logistics and production environments. In a medium-sized company, the amount of paper printed using a printer may be approximately 19000 pcs per year, which consider checklists, forms, diaries of processes or maintenance. This quantity amounts to approximately 1140 EUR. The article focuses on the tools, which are commonly available software to smaller and larger companies in the manufacturing industry, and of course in other industries.

1 Introduction

What is digitization? Jarvis, A. with Morales, L. and Jose, J. said that: "*Digitization is the process of converting information into a digital format*" [1]. Correa da Silva, F. S. and Augusti-Cullell, J. defined, that information is: "*built by an intelligent entity, who constructs and organization for data in order to make sense of it*" [2]. Data digitization represents a huge potential for removing paper from processes in the information flow. Van Eijck, J. and Visser, A. described information flow as: "*metaphor of information exchanges as a kind of liquid flow. After all, we speak of information transfer, flow, and extraction*" [3]. Ultimately, digitization can also has a positive impact on the environment, as companies can spend substantially less paper on their information capture needs. Oláh, J. with Sadaf, R. and Máté, D. and Popp, J. think that: "*the success factors of the business, we have found that trust is the first, sector-specific IT development the second*" [4]. According Weller, S. and Romney, K.: "*the gathering of data is only the first step in the quest for understanding; data must then be analyzed and interpreted*" [5]. Paper forms as a means of recording and transmitting information are therefore slightly declining in industry today. In addition to a variety of internal corporate and corporate software that enables the creation of a digital information stream and, of course, in addition to the extended SAP, Microsoft has also launched Office 365 in 2011. Greve, D. and Strand, L. wrote that: "*for enterprises Office 365 allows them to move operationally important systems such as e-mail out to the cloud with Exchange Online – to be maintained and optimized by Microsoft*" [6].

This article is focused in more detail on how forms applications can be used, along with specific examples of how applications can be used in industry, whether to collect the data needed to manage production or logistics using electronic forms.

2 Methodology

Stack, F.C together with Marmor, M. and Jackson, L.L. have an opinion that: "*Electronic forms are non-paper, machine-readable forms created by forms analysts with the aid of forms design software*" [7]. The range and spectrum of data that can be collected using digital forms is wide. It is certainly interesting for manufacturing companies where is no need to be programmatically skilled to work with a useful everyday data collection tool. O´day, James said interesting idea that: "*Quality of the data depends at least on the performance of the police investigators and of those reviewing the data and entering them into computers*" [8]. Of course, in production aren´t police investigators, but we can find there people responsible for data validation. Systems for continuous data collection automaticly at machines are usually based on integrated own PLC - programmable logic controller. Hansen, D.H. describe the principe of PLC in following way: "*A PLC operates, in principle, in the same way as a PC. This means that a PLC must programmed in order for it to perform its tasks*" [9]. For easier way in collection of data manually there is an option as digital form. It is common to use digital forms to collect data using quizzes and various surveys. Therefore, the use of digital forms is more widespread in areas:

- Marketing.
- Research agencies.
- Conference venue.

In the field of logistics and especially at micrologistics, the principle of data collection is the same, but the data will be different. Exact definition of micrologistics accroding Straka, M. is that: *"micrologistics it is possible to understand distinctive logistics at the level of an industrial concern or another company, the elements of which are the basic and supporting subsystems of the* *busniness"* [10]. If we are considering collecting the data needed for logistics, then we can focus on all parts of the internal logistics of the company. Above all, however:

- Material receipt in small plants.
- Order material from production lines.
- Records of material picking.

When we speak about manufacturing, it was described by Todd, R.H, Allen, R,H, and Alting, L. as: "*an interdisciplinary activity*" [11]. In the area of production, the application is interesting for collecting data on both regular and irregular activities. In particular, however, for capturing data on inspections carried out on production facilities such as:

- Technical inspection of the machine before start of production.
- Check that the machine is lubricated.
- Check the tightening of screws or nuts.
- Traceability of machine cleaning data.
- Check replacement of seals.

In this case, production is slightly data specific, as the data must be easily traceable. For better understanding, traceability is according Coff, C. and Barling, D. with Korthals, M. and Nielsen, T.: "*system refers to how far back or forward the system is able to track and item*" [12]. It is very common to find these data about the process and the performed check in the case of delivery of the complaint and its back clarification, eventually finding a corrective solution, to avoid repeating the error and so on. The data collected in electronic forms have a huge advantage over the paper version because they are:

- Permanent.
- Available.
- Traceable.

The application works on the principle of quiz questions, to which one can answer by choosing from the options or by filling in the text box. Entering responses is manual as it visible in Figure 1.

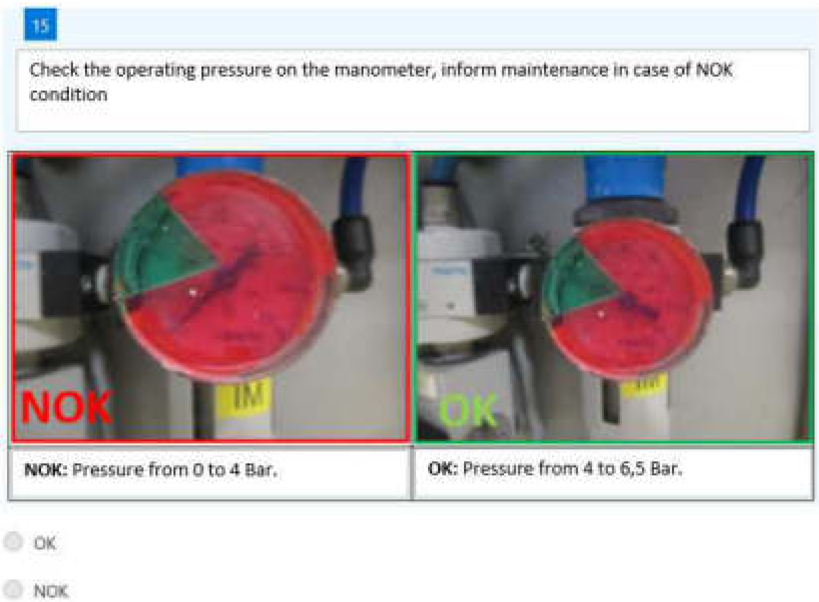

Figure 1 Example of question in forms formular for check the "OK" or "NOT OK" state at facility

Responses or written texts to the application are automatically saved to the collection point, respectively the cloud. Cloud is described by Rajsingh, E.B. and Veerasamy, J. with Alavi A.H. and Peter, J.D. as: "*efficient, on-demand, and scalable environment for the benefit of end users*" [13]. At the collection point it is possible to view and filter the data eg. using Microsoft Excel. It is possible to display the forms as well as the collection point using both a computer and a mobile phone or tablet.

The electronic form can be opened in 2 ways:

- Click the hyperlink;
- Scanning QR codes.

Firstly is needed to say, what hyperlink or hypertext is. Mcknight, C. and Dillon, A. with Richardson, J. writed that: "*simply stated, hypertext consist of nodes (or ´chunks´) of information and links between them*" [14]. Clicking a link can be used primarily in areas where computer access is possible, otherwise a mobile phone or tablet can open the form. After click on the link, you will be automatically connect to the electronic form.

Use of the QR code is possible in areas where the computer is not stable, or if the purpose of the form is to force a person who has scanned the QR code to confirm that he has personally visited and checked the site. This indisputable advantage is not offered by the paper form of the forms. This creates a new dimension of control in time, but also in place. Authors Szewczyk, R. with Zielinski, C. and Kaliczynska, M. agreed that QR codes: "*may also carry useful information that can be easily read by means of a low-cost camera*." In industry it can be read by mobile phones, tablets or scaners [15]. The QR code is a two-dimensional barcode developed by the Japanese company Denso-Wave in 1994. The term "QR" comes from the English designation Quick Response, as the code is designed with a view to quick decoding. After scan of QR code there can be automatic connection for specific digital form - checklist with quiz questions for control of process quality for example as it visible at Figure 2. Advantage is that there is possibility to set also information flow for specific email adresses. For example, for all "OK" replies it has just informative character, but in case of "NOK" reply digital form can show additive questions and after fullfill of form specific informations can be send to specific email adresses. Example is shown at Figure 3.

Everything is designed to make it easier for people to work. Kovács, G. and Kot, S. said that: „*The growing market globalization, increasing global competition*" [16]. About effectivity of work wrote Hackett, P. that: "*Within most work organizations the task of bringing people to the desired standard of efficiency*" [17]. It is important for reason to be a competitively due to large amount of competitors. Kotler, P. and Armstrong, G. described it as: "*an advantage over competitors gained by offering consumers greater value than competitors do*" [18]. Effective work must be standard. Pekarčíková, M. with Trebuňa, P. and Kliment, M. wrote about standardization that: "*The goal of standardization is to stabilize processes, thereby improving productivity, quality and efficiency*" [19].

Figure 2 Representative visualisation of forms at mobile. Author: Ing. Peter Ignácz

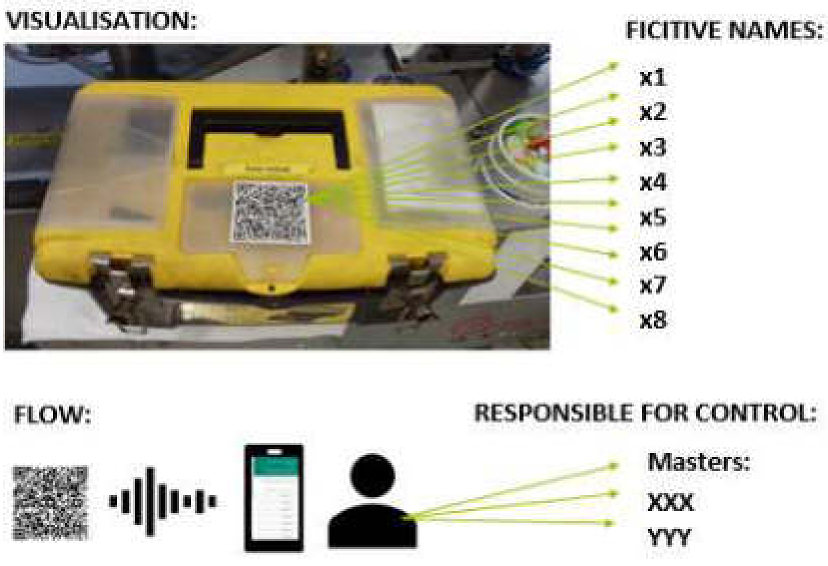

Figure 3 Representative visualisation of forms information flow about tool box cleaning. Author: Peter Ignácz

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3 Result and discussion

Data digitization brings with it a great advantage, namely the possible reduction, respectively. the absolute removal of the paper from the production or supply process. According Dimopoulos, G. it means that: "*To become paperless means, essentially, that the traditional paper-based practices such as writing, note-talking, reading, editing, communicating and even drawing are implemented electronically*" [20]. It means that during change of system from manual writing on paper to digital collection of data there need to by as change of system so change of people and their training. Good opinion have Drucker, D.J. and Bruckstein, J.P.: "*To create a truly paperless office, you will need to adopt a paperless mentality*" [21]. From the legislative point of view, however, it is necessary to ensure that there is still traceability of individual processes and their parameters in case of complaints. In the food industry, these are particularly points CCP – Critical control points. Pierson, M.D. and Corlett jr.:, D.A. see a CCP as: "*A step in a process at which control can be exercised and a food safety hazard can be minimized*" [22]. In the event of a power failure, computer network failure, or overall application failure through which data is collected and written, it is always necessary to keep paper records of the process.

For a simple example of possible cost saving through digitization of forms and also simple calculation of it, the below table of the necessary forms in paper form is operated by a fictitious company based on change, daily and weekly with irregular usage days. It can has impact on fixed cost which are according Bentley, T.J.: "*any cost which does not change in a direct relationship with output*" [23]. Consider production facilities distributed on two floors:

Table 1 Quantity of paper form documents use at production part - A

Per shift:						
Machine:	**Document**	**Pcs/machine**	**Nb of machines**	**Pcs/Shift**	**Pcs / Day**	
Banding machines	register of control	1	3	3	9	
	acceptance protocol	1	3	3	9	
Welding machine	temeprature control protocol	1	1	1	3	
				TOTAL	21	pcs of paper per shift
Daily:						
-	Paper form of sampling			1	1	
					22	pcs per day - ground floor:
Irregular						
Weekly:						
-	Paper form production startup	1			1	approx. 3 per week
					150	pcs per 50 workweeks

Formula for calculation (1):

$$Pcs\ of\ paper\ per\ day\ \times Days\ in\ workweek\ \times Workweeks\ per\ year + Pcs\ of\ irregular\ paper\ forms\ per\ yer = Total\ quantity\ of\ used\ paper \qquad (1)$$

Table 2 Total quantity of used paper at production part - A

Pcs of paper per day	22	
Days in workweek	5	
Workweeks per year	50	
Pcs of irregular paper forms per year	150	
TOTAL	5650	pcs of paper per year

Analysis of the quantity of paper forms used in the production part - B of the fictitious operation.

Table 3 Quantity of paper form documents use at production part - B

Per shift:						
Machine:	**Document**	**Pcs/machine**	**Nb of machines**	**Pcs/Shift**	**Pcs / Day**	
Fillers	shift report	1	6	6	18	
IMIG	shift report	1	1	1	3	
	register of control	1	1	1	3	
PO-CLIP	register of control	1	1	1	3	
	Paper form of sampling	1	1	1	3	
THU	report	1	1	1	3	
Grinders	report	1	1	3	9	
Graphs	viscosity	2	1	2	6	
				TOTAL	**48**	pcs of paper per shift
Daily:						
-	CCP graphs				3	
					51	pcs per day - first floor:
Irregular						
Weekly:						
-	Paper form production startup	1	12	1	2	approx. 12 pcs / week
				TOTAL	**600**	pcs per 50 workweeks

Formula for calculation (2):

$$Pcs\ of\ paper\ per\ day\ \times Days\ in\ workweek\ \times Workweeks\ per\ year + Pcs\ of\ irregular\ paper\ forms\ per\ yer = Total\ quantity\ of\ used\ paper \quad (2)$$

Table 4 Total quantity of used paper at production part – B

Pcs of paper per day	51	
Days in workweek	5	
Workweeks per year	50	
Pcs of irregular paper forms per year	600	
TOTAL	13350	pcs of paper per year

Calculation of savings by reduction of paper forms (3):

$$Total\ quantity\ production\ part\ (A) + Total\ quantity\ production\ part\ (B) = Total\ quantity \quad (3)$$

$$5650\ pcs + 13\ 350\ pcs = 19\ 000\ pcs\ of\ paper\ per\ year$$

For a unit price of EUR 0.06 per 1 piece of paper. The price also includes the cost of operating the printer (toner and energy). Representative calculation of the final form digitization savings per year:

$$19\ 000\ pcs\ \times 0{,}06\ EUR = 1140\ EUR.$$

4 Conclusions

By digitizing data, it is ultimately possible to save financial resources that are tied to paper and the costs associated with operating the printer. This is also visible by calculating the paper that has been saved in a fictitious operation. With an average paper consumption of 19,000 pieces per year in the production process, this allowed a potential saving of 1140 €. If we looked at the company as a whole and not just the production part, this would be even higher. It should be noted that the amount of paper is multiplying in operations where 2 or 3 work changes are being made. This change brings higher demands on the computer skills of people who will come into contact with e-forms and also manage the system. Training personnel to operate and work with these tools is therefore one of the key factors for successful implementation.

The number of forms created for each company is unlimited, as is their form. There are several possibilities of access to forms or other digital documents and it is necessary to set them according to the actual conditions of the workplace and the job description of the worker. It is also possible to open documents by clicking on the hyperlink or by scanning a QR code, which can force the worker to visit the site. However, digitized forms and documents carry another huge advantage, and that is traceability. The data is stored as a virtual storage - cloud, from where it can be accessed from any location and device, and is always fully accessible. There is no need to physically go to the archive if we need to locate the device a month ago at a specific time. These things can be very helpful, for example, in clarifying complaints. Today, this solutions are implemented in many organizations, but not every organization uses the tools in this suite to reduce its fixed costs. The use of instruments is wide-ranging and this article pointed to only one option.

Most companies do this improvements for reason of competitiveness. For large corporations, as well as smaller businesses, it is important to remain competitive. Data digitization is one of the steps to achieve this.

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CONCEPTUAL DEVELOPMENT OF ELECTROMOBILITY IN CONDITIONS OF SLOVAK MUNICIPALITIES

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Keywords: local action plan (LAP), electromobility, charging infrastructure, battery electric vehicles (BEV), plug-in hybrid electric vehicle (PHEV)

Abstract: Development of electromobility depends on several factors. Framework conditions are usually defined at the national level, typically by government, but sometimes the national conditions are also affected by the European framework. The national framework has been developed in Slovakia in recent years in the form of a package of strategic documents that are successively practically realised. The problem is that the framework does not have an adequate response at regional and local levels. The development of electromobility in the conditions of the municipalities will have a relevant impact mainly on the infrastructure. Therefore, the municipalities would be prepared for the development of electromobility. Generally, it should be a document typically covering the medium-time period that defines measures of the municipality and is interconnected with other relevant municipality documents. The paper analyses the benefits and barriers of electromobility and typical car user behaviour generally and specifically in electromobility environment. Then the typical aspects regarding the development of Local action plan for electromobility are presented. Thereafter the process of the plan development and experiences gained during the plan development are described. Finally, the particular measures of Local action plan of e-mobility for Municipality of Senec are stated.

1 Introduction

After a long hesitant attitude, the issue of electromobility has recently become more dynamic in the Slovak Republic. In the past, despite the existence of an initial concept, the approach of competent authorities was without any vision and continuity. At present, thanks to the influence of the European Commission, the situation has changed and Slovakia has developed a comprehensive strategic framework for alternative fuels and, in particular, the Action Plan for the Development of Electromobility in the Slovak Republic. These documents [1-4] create framework conditions and define specific measures at the national level.

To achieve this more effectively and to bring it closer to the citizens, it is also necessary for the self-government to be prepared for these challenges. A conceptual material may be a suitable tool at the municipality level as it can be understood not only by an official of the municipal office but also by a member of the local council and also by a citizen. To fulfil and implement the elaborated material, it should have defined objectives, tools, responsibilities and timeframe - typically it should be a local action plan of electromobility (LAP).

2 Benefits and barriers of electromobility

The issue of electromobility was assigned by the Government of the Slovak Republic to the Ministry of Economy of the Slovak Republic. It addresses the national framework for electromobility in the form of changes to the related legislation, preparing the strategic materials and defining specific measures to support the development of electromobility (e.g. grant schemes) [1-4].

In line with sustainable transport trends, alternative fuels [3-5] are now increasingly preferred, with electricity probably playing a major role in the future. In the case of the deploying of battery electric vehicles (BEV), a significant reduction of local emissions will be achieved (the reduction of total emissions will depend on the way of production of electricity - energy mix) which is very important considering the agglomerations and settlements that are found in poorly ventilated basins and valleys.

Thus, in the case of the use of BEVs, these vehicles (except emissions from tire wear, brake linings and the road itself) do not produce emissions at the local level (at the point of the electric vehicle use), however, emissions are generated at the point of electricity generation. The overall balance is directly related to the greenness of energy sources and it should be noted that there are countries in the EU where the use of an electric vehicle is worse than of a conventional one (e.g. in terms of the balance of CO2 production).

In the previous period, experts discussed the issue of starting a more massive development of electromobility, especially the relation ("vicious circle") between the lack of charging infrastructure and a commercially insignificant number of electric vehicles. However, the obstacles from point of view of users are several [6].

The principal barriers to the development of electromobility are [7]:

- purchasing costs of an electric vehicle,
- insufficient charging infrastructure,
- the lifetime of the electric vehicle's energy storage device,
- usable range on a single charge and charging time,
- unsolved interoperability,
- energy storage security.

Considering the economic aspects (the price of electric vehicles, investments in charging infrastructure), the effort is to start electromobility with support and grant tools. The price of electric vehicles has been steadily declining over time and it can be assumed that in the medium-term horizon these will be competitive with conventional vehicles (also due to their increasing technological regulation). The charging infrastructure is still insufficient and in the city conditions (manly in the high-density settlements with block of flats) the new approaches will have to be found (e.g. application of layer-based solution [8] or energy hubs [9]). Technological advances are also gradually bringing solutions that address the endurance distance of electric vehicles and charging speed. The solution of the historical problem of incompatibility of charging systems is also being solved, e.g. National policy for the implementation of infrastructure for alternative fuels in the conditions of the Slovak Republic [4], but it remains to solve payment and information interoperability. The safety of electric vehicles is still a problem, although, not so significant. The problem is the energy storage device (i.e. the accumulator, although the battery designation is generally accepted at the professional level), which is usually lithium-based and which can ignite (not only when damaged) and cannot be extinguished conventionally.

2.1 *Users behaviour*

One of the above barriers is still perceived by the optics of the experiences of conventional car drivers who are used to range up to 1,000 km. On the other hand, there is the aspect of typical vehicle use (Fig. 1) and also the specific use of an electric vehicle with a relatively lower range (sufficient for supply purposes, service systems, etc.). Thereafter it is clear that currently available electric vehicles fulfil a significant part of the use cases.

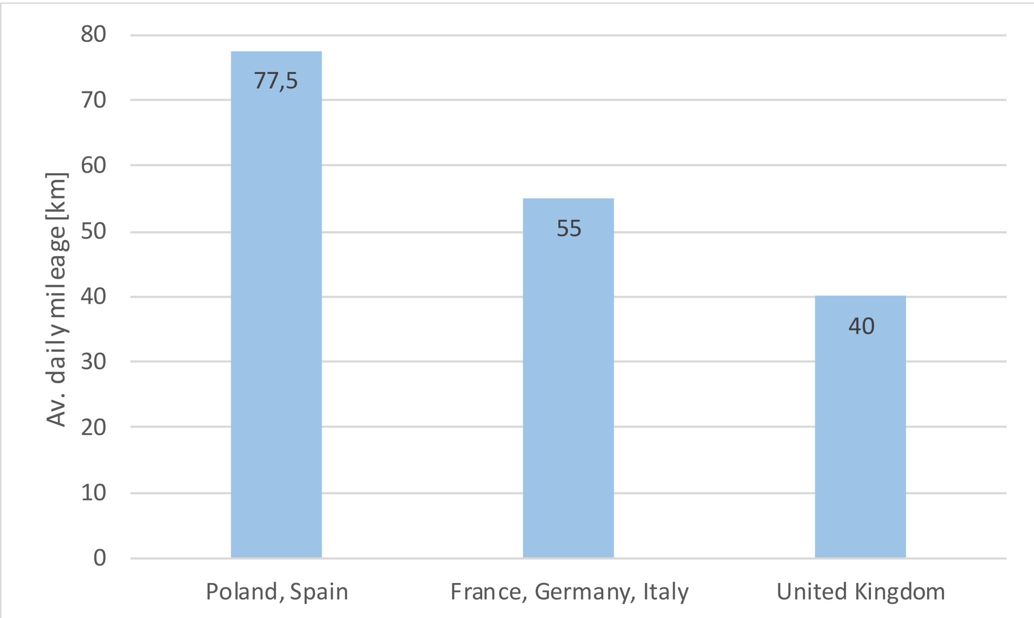

Figure 1 Average daily mileage of vehicles in specific countries (all vehicles, i.e. mostly conventional) [7]

Considering the perspective of the charging infrastructure, it is important to understand the behaviour (needs) of electric vehicle users. Typical user behaviour at the charging stations in the developed market (Netherlands), i.e. the effective use (charging) ratio and the inactivity ratio depending on the daytime are shown in the following Fig. 2. It follows that more than half of the time an electric vehicle was connected to a charging point the vehicle was not being recharged but only occupied a parking place equipped with charger. Certainly, this phenomenon is not desired because decreases efficiency of charging points utilisation.

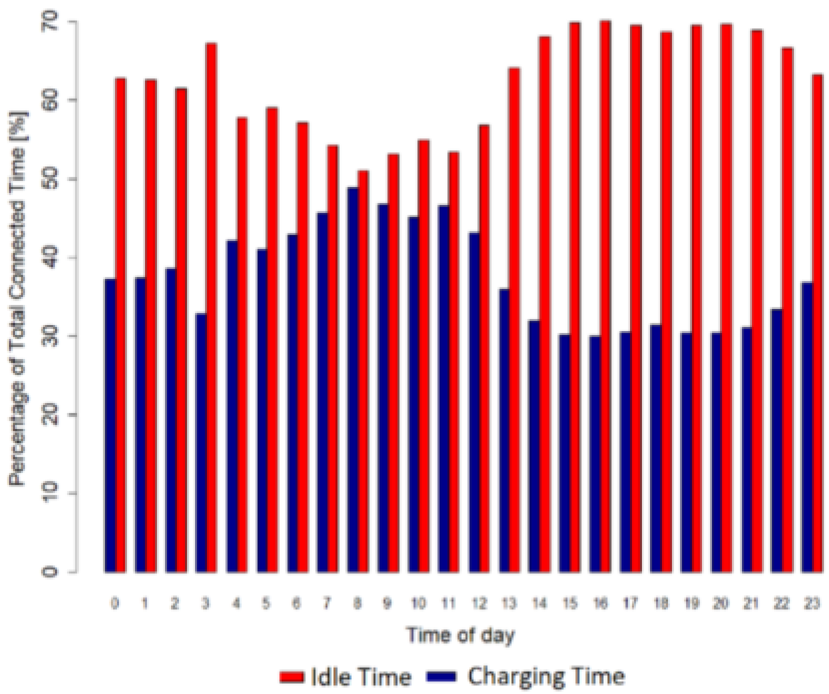

Figure 2 Users behaviours at the charging stations [10]

The requirements of users are time-dependent and are typically different on weekdays and weekends (Fig. 3).

Each point represents the initial time of charging process. It is obvious that utilisation of the charging points during working days and weekends differs. During weekdays two narrow peaks can be observed (7:30 and 17:30) and between these two periods the relatively stable trend can be seen. On the other hand, most of the charging sessions start at midday and the peak is much wider at weekends.

The analyses of extensive data from charging stations point to a clear segmentation of users. However, it is possible to identify groups of users who charge a battery electric vehicle (BEV) or a plug-in hybrid vehicle (PHEV):

- at home,
- at work,
- charging related to other activities (shopping, culture, sports, ...),
- travelling purposes (i.e. for distances which are longer than the range of an electric vehicle, typically intercity journeys).

Typical usage of the charging infrastructure on working days is shown in the following Fig. 4, which shows the number of transactions categorized by arrival and departure times (rounded to hours). The size of the circle is proportional to the number of transactions in a given hour, and the colour of the circle indicates the charging rate (ratio of charge time and connection time).

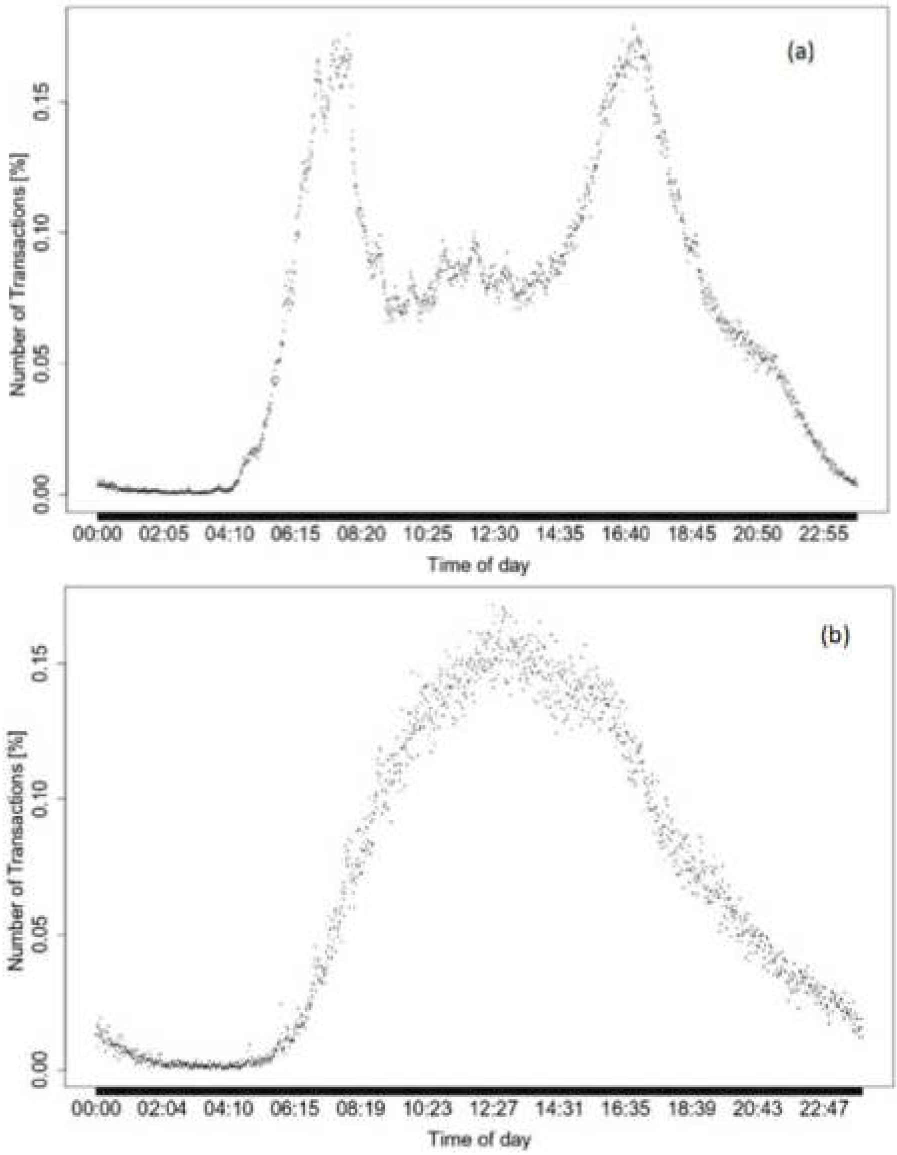

Figure 3 Initial charging time a) working days, b) weekends [10]

Such analyses are important from practical and business point of view, e.g. clustering of the transactions can help to dimension (power and number of charging points), allocate and set up the business model.

3 Local electromobility action plan

Regarding to the above mentioned, it is clear that a significant proportion of BEV and PHEV users use the infrastructure at their place of residence, work or facilities. Furthermore, taking into account that available electric vehicles are suitable for urban or regional transport, whether for individual car transport or urban public transport (e-bus), service systems, etc., it is obvious that electromobility has its merit in urban conditions. The self-government should, therefore, respond to this trend and address it within its competences conceptually taking into account its specificities.

3.1 Local electromobility action plan in general

In terms of transport and mobility problems, smaller towns in the Slovak Republic are under-sized in terms of personnel, and often this area of competence is attached to the section dealing with construction issues. In many cases, they do not have professionally trained capacities and the activity itself usually focuses on permitting procedures, road maintenance and public transport services in the city.

It is therefore in the interest of the city to address the issue with solving the electromobility in the city in cooperation with external capacities that will bring a different perspective on the state, problems and processes in the city.

The quality of the output - LAP depends not only on the expertise of the involved persons and subjects but also on the available database. The availability of data for LAP development is usually closely related to the availability of other high quality and relevant documents of the city and region, covering mainly transport, economic and social aspects (Plan of economic and social development, Transport master plan, Spatial plan, Sustainable urban mobility plan, Sustainable energy action plan, Cycling strategy, City logistics conception, ... [11,12]).

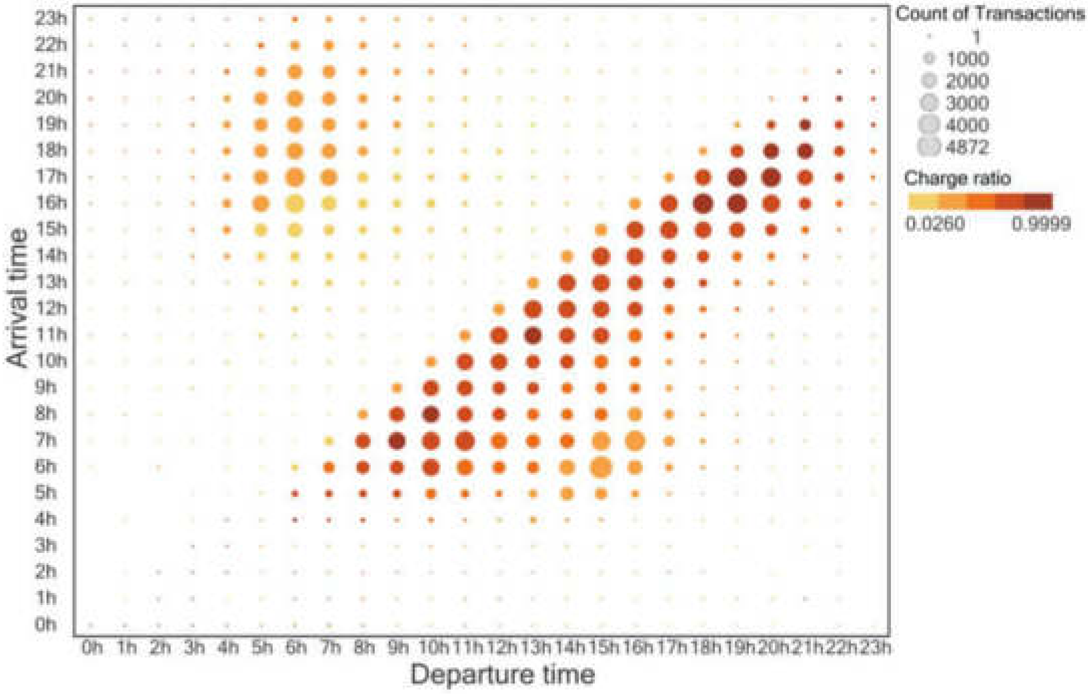

Fig. 4 Arrival and departure times (plug-in and unplug of eV) portraying the charging ratio and number of transactions [13]

3.2 *Local electromobility action plan in Senec*

The Municipality of Senec is actively involved in the Interreg Danube Transnational Program by the project devoted to the Electric, Electronic and Green Urban Transport Systems (eGUTS) [14], which aimed to develop a local electromobility action plan for Senec.

Senec (approx. 20,000 inhabitants) is a district town situated in the south-west part of Slovakia, 25 km north-east far from the capital Bratislava. It has a flat character and very good traffic position. The motorway D1 Bratislava - Žilina is passing nearby and the main railway line Bratislava - Štúrovo passes directly through the city. The M. R. Štefánik Airport in Bratislava and the border crossings to Austria and Hungary are also relatively close.

The LAP process consisted of several areas:

- an analysis of relevant documents at the national, regional and local levels,
- an analysis of the current state in the area of (e-) mobility, transport infrastructure and related areas,
- meetings, training, brainstorming,
- communication (telephone, e-mail, teleconferencing).

It should be noted that at the time of LAP preparation only Plan of economic and social development and partially Spatial plan were available in Senec. The development of the Transport Master Plan was interrupted at that time due to major infrastructure changes in the surroundings of the town, so a lot of necessary current data and transport forecast absented [12]. For that reason, personal meetings with the responsible staff of the Municipal Office were important, as they provided information that was not captured by any documents and materials to the investigators.

The LAP was prepared for the municipality as a document with two parts - analytical and proposal one - and annexes [15].

The following topics were parts of the analytical part:

- electromobility in the European context, trends in the EU, EU legislative and strategic frameworks,
- electromobility in Slovakia, policy framework and strategic documents of Slovakia,
- municipality of Senec, general characteristics of the town and its surroundings, statistic indicators,
- transport in the municipality, the fleet of the municipality Senec, public transport of the Senec,
- traffic in Senec and its surroundings, basic data on the road transport, accessibility in the town, road network load, the prognose of the road network load,
- externalities caused by transport, the contribution of electromobility to the emissions reduction,
- development of electromobility, analysis of economics of electric vehicle.

Within the proposal part, framework measures were identified (update of the town policy; indirect electromobility support; electromobility education, information and promotion; green public procurement principle of the town and town entities; promotion of electromobility infrastructure and services), each consisting of sub-actions that specify individual activities. The description of each measure was defined by the format agreed within the eGUTS project consortium; the description of each measure was realized in the following extent:

- Reference number
- Action/project name
- Strategic document identification
- Action/project description
- Timeframe
- Cost estimation/budget
- Financing sources
- Potential risks and barriers
- Mitigation measures
- Estimated impact
- Project phases
- Action/project holder/responsible department
- Project custodian

Each measure is briefly described by its name with a description of the corresponding actions (sub-measures).

1 Update of the town policy

1.1. Consideration of the issue of electromobility in the strategic and planning documents of the town with specific emphasis on new territories

1.2 Consideration of aspects that support the development of electromobility (construction of public charging stations, electric car parking, etc.) when developing projects (e.g. public buildings, transport infrastructure construction/reconstruction, underground services construction/reconstruction) and suggesting new building areas

2 Indirect electromobility support

2.1 Motivational parking system

- reserved parking places for BEV / PHEV
- reduced pricing policy for BEV / PHEV
- reserved parking at the BEV / PHEV operator's residence

2.2 Regulation of the entry of service transport systems into the reserved areas of the town within the specified time (peak hours)

- without limitation for BEV / PHEV

2.3 Preference of e-TAXI

3 Education, information and promotion of electromobility

3.1 Active organization, engagement and support of the information and awareness-raising actions on electromobility and green transport (European Mobility Week - 16-22.9; Car-free day - 22.9.; (E-)Bike to Work (every year in May), mobility day, schools, support of third-party information actions)

3.2 Integration of available information on electromobility (static and dynamic data on charging infrastructure within the town, information on indirect support for electromobility, information on support schemes, etc.) into a single site, together with related traffic information

3.3 Building of a public-private platform to support electromobility in the town using the information and experience from the eGUTS project.

4 The green procurement principle of town and town entities

4.1 Optimization of the fleet tailored to the needs of the town and its entities (increase the vehicle utilization and thus its economic efficiency; possibly reduce their number)

4.2 When renewing the fleet of vehicles, consider replacing by an electric vehicle or another transport mean using the principles of green procurement

4.3 Use of support and subsidy schemes for legal entities and public sector to support electromobility (electric vehicles, charging infrastructure, education, etc.)

5 Support for electromobility infrastructure and services

5.1 Building of a basic scheme of public charging stations (managed by the town or by a partner), including the installation of 1-2 charging stations from the eGUTS project.

5.2 Based on the results and experience gained from the eGUTS pilot project on electric bicycles, consider further extending of the e-bike-sharing scheme (electric bicycles, charging stations)

5.3 Assessment of the scope of public transport and an adaption of timetables to the needs of passengers (the needs of passengers arise from the general plan of transport and these requirements need to be adapted mostly from the time point of view - coordination within the integrated transport, beginning and end of classes at schools, nursery schools, etc.)

A part of the proposal section is also a description and an explanation of each measure together with a proposal for the implementation of the measure up to the individual project phases.

In case of adoption of other strategic documents that may have an impact on the LAP (Transport master plan, Sustainable urban mobility plan, Sustainable energy action plan, Cycling strategy, etc.), the LAP needs to be updated so that these documents form a complex but coherent ecosystem.

4 Conclusions

The primary role in fulfilling the defined measures and objectives of the LAP is played by the self-government – Municipality of Senec. Of course, the Municipality itself cannot create the necessary framework ("ecosystem") at the local level. This framework interacts with many entities similarly as it is in the Smart City concept. To implement the framework successfully, it is necessary to cooperate with all participants who can help the town to achieve the goal - public, third sector, education institutions, private sector.

The result will then be an increase in awareness (Smart People in the Smart City concept) and a continuously balanced increase in electromobility in the town without significant excesses (e.g. excess demand for charging compared to supply or vice versa, or insufficient energy infrastructure for charging infrastructure needs).

Considering the rapidly changing world of electromobility, not only the political national framework but especially technological development, it will be necessary in the future to update the LAP and adapt it to current needs. The update period should be 2 years.

The town Senec is interested in continuing in the strategy of development of electromobility in the European Union and in the Slovak Republic and aims to build an "ecosystem" with a gradual reduction of emissions from the perspective of local transport as an ecological alternative which contributes to increase in the quality of life in cities by eliminating emission burden and acoustic smog. In the recent past, several strategic documents defining the electromobility framework have been developed in the Slovak Republic at the national level, and they should be subsequently transformed into specific implementation and support measures. However, it can be assumed that the overall ecosystem will be substantially affected by the consistency of national policy and the promotion of electromobility.

The Municipality of Senec has been actively involved in projects and support actions related to electromobility and it also intends to continue to act. It has also initiated the e-mobility Local Action Plan for the town Senec and considers it seriously. It is aware of the dynamic environment not only in terms of technological progress in the field of electromobility but also in the regulation of the automotive industry and it is therefore essential to be fully prepared for the rapid development of electromobility in the medium-term horizon.

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FORECASTING DEMAND IMPROVEMENT FOR REPLENISHMENT IN A RETAIL PAINTING COMPANY

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Keywords: forecast, MAPE, service level, economic order quantity, inventory management
Abstract: This case study was developed in a retail painting company; the main objective is to reach a higher cash flow for assuring the fulfilment of the demand with a 95% service level. Currently, supply chain faces to multiples competitors so familiar business have to improve the logistics processes for remaining in local, national and international markets. Through the ABC-classification, the product portfolio was classified for choosing the products with more significative impact. Forecasts techniques may obtain data with higher accuracy in the order preparation. For this research, a seasonal model is functional, since the demand tends to have a similar behaviour year by year and month by month. Seasonal demand model was used to find specific products that might not fit for ordering minimum quantities which might exceed the forecasted demand. On the other hand, classic EOQ model considers the value of the inventory and demand forecast, which demonstrates that the performance of the supply chain could improve considerably. Therefore, an accurate estimate can reduce inventory costs in each of the periods, satisfying customer demand, by at least 14%. EOQ model should apply to all products for reducing the investment in slow-moving stock and improving the inventory for those highly demanded products which can generate flexibility to embrace market complexity and meet customer expectations. As a future study, the company can develop a strategy to reduce non-rotating inventory with more accurately, what and when they will sell specific products.

1 Introduction

This case study was developed a retail store of paintings because of; currently; consumers prefer buying from retailers because their trust is a sensible expectation [1]. Hence family firms are supposed to be more trustworthy compared to their nonfamily counterparts [2-4]. Therefore, family firms may obtain a strategic advantage based on policies and practices that cause them to appear to be more long-term oriented, credible, and reliable [5]. Capitalisation plays an essential role in the success of family firms [6-8]. Consequently, supply chain managers have to adapt their strategies to minimise inventories and maximise sales for facing their competitors [9]. It is crucial that calculates demand forecasts for decision-making that satisfy customer needs without having an excessive inventory to have a higher cash flow. For it, the company's portfolio products should segment through the ABC methodology, which acknowledges, which products are the most representative in terms of value-use.

ABC classification can help industrial marketers in three ways: costs estimate of products with significant differences specifications, proposing which product specifications may adjust in negotiations, and indicating the change company operations to reduce the cost that will allow satisfying customer [10]. Therefore, accurate and robust classification of items is required to manage a large number of products. ABC analysis, which is based on Pareto's principle, requires a single criterion, annual usage value (cost). Few items, which contribute a considerable amount of yearly usage value, are considered as A-class items and which provide very less amount of annual usage value, are considered as C class and B class. However, most of the companies store thousands of products and often they are not correctly categorised.

Additionally, ABC classification does not consider lead-time, inventory cost, commonality, obsolescence, substitutability, number of requests for an item per year, number of purchase orders per year, purchase order size of an item, scarcity, durability, repairability, stock ability, demand distribution and stock-out penalty cost, among others things [11]. To achieve supply chain competitiveness, having accurate data is a crucial factor

[12]. However, supply chain managers cannot guarantee the accuracy of the forecasts [9] because the demand uncertainty and fickle consumers which unwilling to wait for replenishment if a product is momentarily unavailable [13,14]. Therefore, many supply chain managers rely on large inventory holdings as buffers to reduce the risk of product unavailability [15], which is not only costly but also generates inefficiencies throughout the supply chain.

Based on the case study company policies, materials should be ordered weekly. Therefore, supply chain management (SCM) supports to manage inter-company material, information, and financial flows to collectively enhance productivity, performance, and profitability [16,17]. Low costs across the supply chain, in addition to appropriate customer service levels, is seen as a crucial success factor [18]. Inventory management plays a vital role in obtaining a competitive advantage. Hence the main objective of inventory management practices is to have the requirements at the right time, in the right place with minimum cost. This proposal methodology reduces inventories, predict the demand for all A, B, and C classification SKUs, for each of the months and in turn have money available to invest on those materials with higher rotation or other special needs that arise.

2 Background

The proper management of assets held within an organization can be studied through inventory management models that is the reason for research and in-depth analysis, as they constitute an essential item on the financial statements of any company. Optimizing the operation and management of these assets to achieve the fulfilment of its function without incurring excessive expenses is the objective of using these models and management tools.

The three key questions inventory management attempts to answer are i) How often should the inventory be reviewed? ii) When should an order be placed? iii) What size should the order be? [19].

The most common objectives when applying a management model are [20]:

- Minimize costs incurred by inventory management;
- Maximization of economic benefits, speaking of savings;
- Maximization of internal rate of return on inventory investment;
- Determine a feasible solution for better inventory management;
- Ensure flexibility in handling;

Faced with variations in demand and delays, organizations decide to work with safety stocks; this allows them to maintain the level of service that is vital to their operation [21].

Chikan [22] talks about a paradigm shift in business on different topics, as shown in the below table (Table 1).

Table 1 New paradigms in inventory management

FIELD	PARADIGM
Economy of services	**The requirements of today's customers are not merely to buy products, but to obtain solutions to their problems. Companies must offer the exact combination of products and services.**
E-Economy	**ICTs can achieve a level of integration in the activities, increasing availability, speed of action, and reaction.**
Network economies	**Competition is now between networks, so cooperation and competition are now interrelated. Achieving long-term relationships and strategic alliances.**
An economy based on knowledge	**Achieve competitive advantage through experience. Companies need more and better information based on more sophisticated decision processes.**
Responsible economy	**The actors within the economy are obliged to consider not only their interests but with all their surroundings.**
Global economy	**Decision-makers should consider the global economy when investing, buying, or selling, as competitors, customers, and partners can come from anywhere.**

The new paradigm is that inventories should now be an integral part of the value chain and in close relationship with other functions of the organization, thus becoming a strategic tool that achieves economic benefit and customer satisfaction, and their performance measures should be based on their contribution to finding better solutions for the consumer than those offered by competitors [22,20]. Customers expect immediate gratification from suppliers regarding their requirements, just as they have them with their customers or suppliers, but as Walker [23] states, they do not consider a different sourcing pattern. Therefore, it is necessary to make a sourcing plan that ensures the satisfaction of the requirements of retail customers. Regarding the analysis of demand, according to Howleg [24], the first step is to understand that there will be a difference between the real demand for materials and what is called artificial demand generated from organizational decisions. It is taken from the information that is available from customers, as well as the needs of the company itself, to know the demand from a forecast based on the behaviour of customer demand.

Walker [23] believes that perfect compliance is one in which the right product can be delivered at the right price, time and quantity, meeting the stipulated quality standards. So, it is essential to start focusing on making consistent, reliable deliveries that achieve perfect compliance. Howleg [24] states that because customer demands are unstable and highly variable, companies are required to have a safety stock. Dwivedi and Butcher [25] point out that proper management of information is of paramount importance, as it can be used to optimize supply chain relationships, avoiding internal and external problems. Eagle [26], mentions that while forecasting, it should be considered accuracy of approximately 80%, with variability that can have up to 40% additional, which as a result, will generate unbalanced inventories and prone to customer service gaps. Selecting from a variety of forecasting methods, the one with the highest accuracy plays a crucial role in the satisfaction of the company's customers.

2.1 ABC classification and EOQ model

For the present demand analysis, the ABC inventory classification technique is used, which is defined as an inventory control method based on the principle discovered by Pareto, who observed that 20% of the Italian population owned 80% of the land used, and later found that this principle could be applied to the economy [27]. The ABC methodology divides the company's sales into A for those SKUs which represent 15-20% of the inventory and whose profit to the company's revenue is close to 80%; the B classification is for those products that are in stock with 30-35% of the volume and represent 15% of the profits, and finally the C class is for 50% of the items in inventory that contribute to 5% of the sales [28].

The classic EOQ concept equation 1 is born from the minimum intersection of the costs of maintaining the inventory with ordering costs; in this way, it can be assumed that it is an optimal value of units to be requested at the minimum possible cost [29].

$$Q^* = \sqrt{\frac{2(D)(C_O)}{Ch}} \qquad (1)$$

Where:
$Q*$ = economic order quantity,
D = forecasted demand in the planning horizon,
Co = ordering cost per unit in the planning horizon,
Ch = holding cost per unit in the planning horizon.

Given that the company studied is a retailer, the allowable costs will be proportional to the total income, which must be considered in its finances, thinking that if the cost is less than the permissible point, it is a profit, or it would otherwise represent a loss [30].

3 Research methodology

This research was developed in different phases (figure 1):

a) Problem statement which describes the actual situation and needs of improvement in the logistics process,

b) information was collected on 52 weeks of sales in the company's product portfolio within five branches,

c) ABC analysis to determine those products which represent approximately 80% of the SKUs,

d) Demand forecast of A classification items looking for a maximum error of 10%,

e) Inventory management, all active products in the portfolio must be kept in inventory, playing a key factor being able to determine a stock level that balances the level of service with the costs of inventory and associated with maintaining it, without impacting the company's cash flow,

f) Results analysis for making-decision.

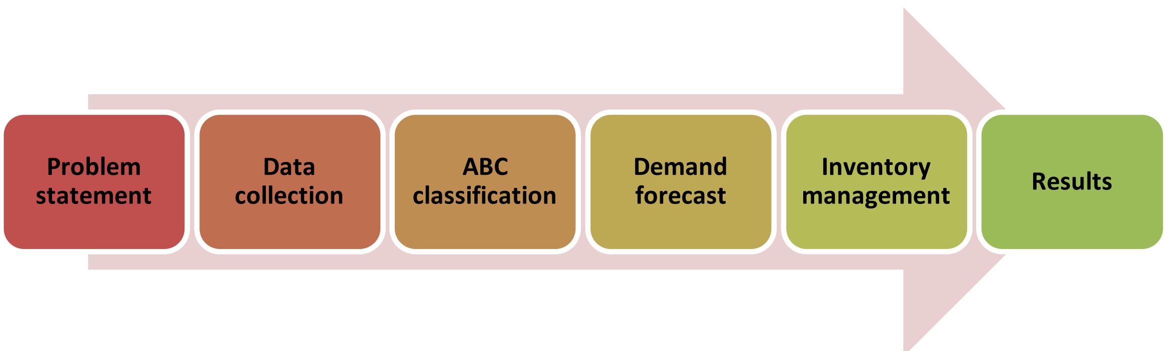

Figure 1 Phases of case study

4 Case study

4.1 Problem statement

The case study was conducted in a family business of paintings which has many deficiencies due to lack of knowledge for decision-making of owners who are managers of the company. One of the main constraints faced is resistance to changes in strategies, due to the belief that current methods are functioning well, and it is not worth generate higher risk. Hence any improvement represents one of the biggest challenges so that the company has higher cash flow with lower inventory and maintaining the service level that has been handled since

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the beginning of the company. In the same way, there is the limitation of available working capital, since the reduced workforce and resources do not allow innovations to be made to the process for improvement projects to be developed. Furthermore, the company has excess inventory which generates high unnecessary holding costs that represent a constraint in terms of cash flow and space.

According with a company record, lost sales have reached 5% of yearly revenue due to shortages in high rotation items for the lack of financial capacity to pursue spot projects because of the elevated value of non-moving inventory. Another important implication is for certain B or C classification products its expiration dates exceed demand which causes additional fees for disposal of dangerous goods. Additionally, the inexistence of an accurate demand forecast and inventory planning strategy are impacting service level. Based on talks with the directors of the company, it is becoming more often that customers do not find the products approximately 5% of the times which is the company's allowance maximum value to keep a strong relationship with their clients (service level target of 95%). The purpose of this case study is applied ABC classification, forecasting techniques and EOQ model for increasing the cash flow monthly and service level.

4.2 Data collection

The data collection consisted of retrieving sales history from the company's ERP from the last twelve months. However, the data showed high variation, so that the sampling period was extended by thirty-six months. This sales history allowed to observe correlation and seasonality among similar periods over the years (Figure 2).

An A-class product was randomly selected to present a chart that describes the behaviour of the demand, it was observed that not all products have the same seasonality, however correlation between months over the years is pretty similar. From below chart, month 12 is the forecasted value as at the time of the development of the paper.

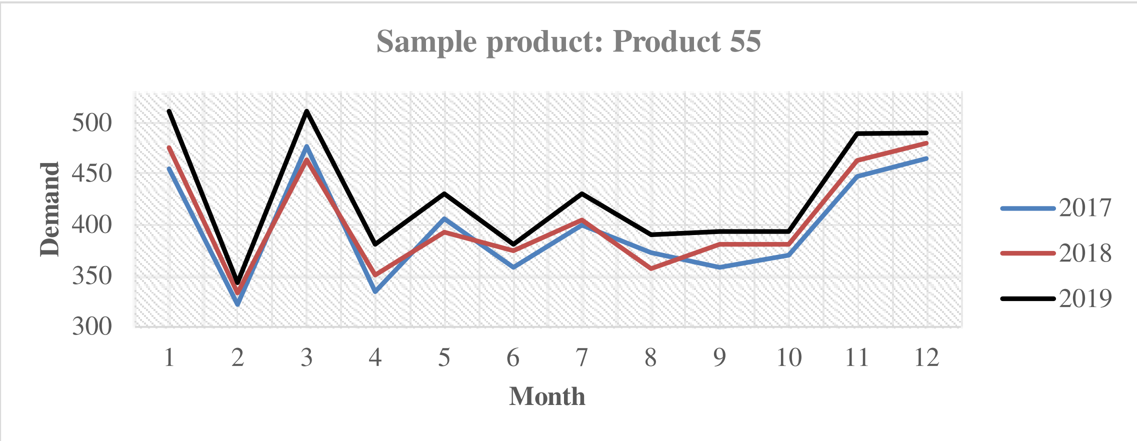

Figure 2 Monthly seasonality over the years

4.3 ABC classification

The total portfolio of the company consists of more than 1500 SKUs, which are necessary to keep in inventory and ensure service level. The higher value and rotation of a product, the more contribution on the sales it has and therefore it has a better ranking in the ABC. It was found that only 56 SKUs fit A-class category, representing close to 75% of total sales, in contrast to the C-class products which represent more than 50% of the portfolio and only worth 5% of sales. Because of the significant impact on revenue of A-class products which are the main focus for applying techniques that improvement the processes logistics for increasing the levels service.

4.4 Forecasting

Once the analysis of the forecasts with traditional methods of time series (linear regression, simple exponential smoothing, Holt-Winters method, simple moving average, weighted and centred) was carried out, it was concluded that none of the models presented results that could approximate the demand of the products, having high errors than the objective established of 10% (Table 2). The centred moving average had the lowest average percentage error (MAPE 26%), without reaching the desired value (10%). However, this method consists of taking a group of observed values, calculating the average, and using it as a forecast for the following period only [32].

Table 1 MAPE results for time series forecasts for A-class products

PRODUCT	LINEAR REGRESSION	SIMPLE MOVING AVERAGE	CENTRED MOVING AVERAGE	WEIGHTED MOVING AVERAGE	SIMPLE EXPONENTIAL SMOOTHING	HOLT-WINTERS
1,…,56	**36%**	**39%**	**26%**	**40%**	**39%**	**37%**

For a forecast to be considered adequate, it is essential to remember that the value of the MAPE must be no more than 10%, the same value that was established as the objective for the analysis developed. Due to the 56 products of A classification show correlation and seasonality as well as external factors that intervene and motivate customers to buy certain products. For the demand of 52 weeks was applied a seasonal forecast that knowing the market trend in recent years will make it possible to adjust the amount of material that will be required in each of the months for the following periods.

Within a seasonal forecast, it is vital to consider three critical components which are: first the level, which allows separating the seasonality of the base values of the estimates. In the second place, seasonality, which will modify the values for the seasonal variations that are shown in the estimates and, finally, the tendency value that will allow adjusting the estimate to the variations or propensities through time [33].

Once the demand per month has been consolidated over the last three years, the average demand is calculated for each of the months during the period stipulated by equation 2. Subsequently, the seasonality index is obtained for each month (equation 3). Afterwards, estimate the annual demand for the year to be forecast as the product of equation 4 by equation 5. And finally, obtain the product of equation 5 by equation 3, with this, it is possible to know the forecast of seasonal sales.

$$P_i = \frac{\sum_{j=1}^{m} D_i}{m} \tag{2}$$

$$S_{index} = \frac{\frac{1}{n}\sum_{j=1}^{m} D_{ij}}{\frac{1}{n}\sum_{j=1}^{m} D_i} \tag{3}$$

$$T_i = \frac{D_j}{D_{j-1}} \tag{4}$$

$$D_{monthly} = \frac{D_j}{n} \tag{5}$$

Where:
P = Average demand in the sampled period,
D = Demand in the planning horizon,
S_{index} = Seasonality index for each of the periods in the planning horizon,
T = Projected tendency year over year,
$i = 1,2,\ldots,n$ (months),
$j = 1,2,\ldots,m$ (years).

It is observed that in the months where there are demand peaks, the index is equation 3 is greater than value 1 during the months of lower sales concerning the forecast average, equation 3 will have a value less than 1, which is the factor between the seasonality compared with the average demand historical data for period i for each of the items (Table 3).

MAPE for the A-class sample of 56 products yields a value of 9.18%, so that meets the objective of 10% error in 53 of 56 articles studied, which will allow replicating the model to the category A products within the company's portfolio with an accuracy in demand forecast of at least 90% (Figure 3), this result is considered highly reliable [34]. Table 4 shows the demand forecast.

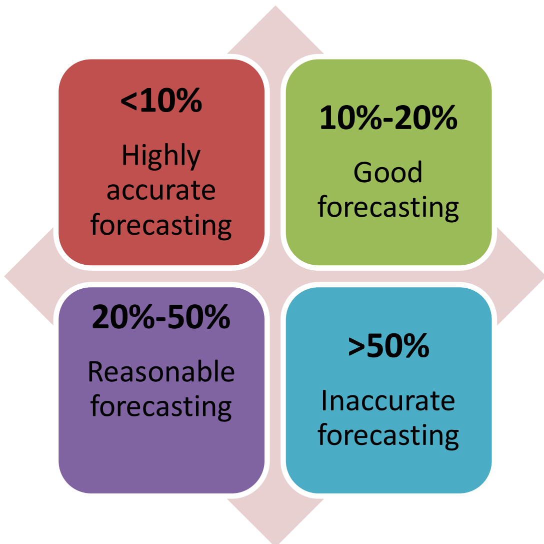

Figure 3 MAPE evaluation criteria

Table 3 MAPE results for seasonal forecasts of A class SKUs

ITEM	PERIOD										MAPE
	1	2	3	4	5	6	7	8	9	10	
PRODUCT 1	**0.05**	**0.06**	**0.03**	**0.05**	**0.02**	**0.08**	**0.04**	**0.08**	**0.05**	**0.04**	**5.12%**
PRODUCT 2	**0.04**	**0.04**	**0.14**	**0.15**	**0.08**	**0.04**	**0.17**	**0.11**	**0.00**	**0.16**	**9.39%**
PRODUCT 3	**0.04**	**0.04**	**0.04**	**0.13**	**0.04**	**0.21**	**0.20**	**0.06**	**0.06**	**0.04**	**8.72%**
PRODUCT 4	**0.04**	**0.04**	**0.04**	**0.12**	**0.04**	**0.06**	**0.10**	**0.03**	**0.04**	**0.21**	**7.36%**
PRODUCT 5	**0.13**	**0.11**	**0.09**	**0.07**	**0.03**	**0.14**	**0.09**	**0.07**	**0.04**	**0.04**	**8.37%**
PRODUCT 6	**0.04**	**0.06**	**0.07**	**0.05**	**0.05**	**0.04**	**0.15**	**0.13**	**0.13**	**0.07**	**7.87%**
PRODUCT 7	**0.14**	**0.04**	**0.20**	**0.01**	**0.00**	**0.04**	**0.24**	**0.09**	**0.04**	**0.15**	**9.69%**
PRODUCT 8	**0.12**	**0.09**	**0.09**	**0.16**	**0.04**	**0.11**	**0.06**	**0.04**	**0.04**	**0.04**	**7.96%**
PRODUCT 9	**0.07**	**0.39**	**0.33**	**0.14**	**0.04**	**0.24**	**0.04**	**0.11**	**0.90**	**0.14**	**24.20%**
PRODUCT 10	**0.02**	**0.16**	**0.03**	**0.08**	**0.04**	**0.23**	**0.07**	**0.15**	**0.02**	**0.03**	**8.32%**
PRODUCT 11	**0.16**	**0.04**	**0.09**	**0.15**	**0.04**	**0.04**	**0.11**	**0.10**	**0.01**	**0.17**	**9.16%**
PRODUCT 12	**0.10**	**0.17**	**0.04**	**0.04**	**0.13**	**0.03**	**0.02**	**0.18**	**0.04**	**0.04**	**8.12%**
PRODUCT 13	**0.04**	**0.04**	**0.04**	**0.13**	**0.04**	**0.10**	**0.04**	**0.04**	**0.06**	**0.04**	**5.95%**
PRODUCT 14	**0.09**	**0.00**	**0.06**	**0.10**	**0.01**	**0.04**	**0.01**	**0.29**	**0.19**	**0.09**	**8.71%**
PRODUCT 15	**0.10**	**0.04**	**0.06**	**0.13**	**0.04**	**0.04**	**0.12**	**0.15**	**0.01**	**0.09**	**7.82%**
PRODUCT 16	**0.12**	**0.10**	**0.09**	**0.17**	**0.04**	**0.04**	**0.06**	**0.12**	**0.04**	**0.07**	**8.49%**
PRODUCT 17	**0.04**	**0.04**	**0.04**	**0.36**	**0.10**	**0.04**	**0.04**	**0.21**	**0.04**	**0.04**	**9.70%**
PRODUCT 18	**0.10**	**0.10**	**0.13**	**0.17**	**0.10**	**0.04**	**0.10**	**0.04**	**0.03**	**0.10**	**9.23%**
PRODUCT 19	**0.08**	**0.24**	**0.03**	**0.14**	**0.04**	**0.08**	**0.03**	**0.04**	**0.04**	**0.06**	**8.00%**
PRODUCT 20	**0.24**	**0.13**	**0.13**	**0.04**	**0.04**	**0.16**	**0.04**	**0.10**	**0.04**	**0.06**	**9.99%**
PRODUCT 21	**0.10**	**0.04**	**0.16**	**0.17**	**0.01**	**0.13**	**0.03**	**0.10**	**0.10**	**0.01**	**8.60%**
PRODUCT 22	**0.11**	**0.04**	**0.04**	**0.04**	**0.17**	**0.04**	**0.04**	**0.33**	**0.04**	**0.04**	**9.17%**
PRODUCT 23	**0.04**	**0.13**	**0.04**	**0.04**	**0.21**	**0.13**	**0.21**	**0.04**	**0.04**	**0.04**	**9.37%**
PRODUCT 24	**0.16**	**0.09**	**0.07**	**0.00**	**0.08**	**0.02**	**0.17**	**0.01**	**0.15**	**0.04**	**8.04%**
PRODUCT 25	**0.03**	**0.06**	**0.11**	**0.16**	**0.18**	**0.10**	**0.05**	**0.14**	**0.08**	**0.03**	**9.46%**
PRODUCT 26	**0.15**	**0.13**	**0.13**	**0.08**	**0.02**	**0.04**	**0.06**	**0.02**	**0.01**	**0.06**	**7.11%**
PRODUCT 27	**0.10**	**0.16**	**0.08**	**0.02**	**0.11**	**0.11**	**0.19**	**0.06**	**0.05**	**0.04**	**9.16%**
PRODUCT 28	**0.04**	**0.13**	**0.08**	**0.08**	**0.17**	**0.13**	**0.01**	**0.16**	**0.04**	**0.06**	**9.15%**
PRODUCT 29	**0.04**	**0.00**	**0.04**	**0.08**	**0.09**	**0.43**	**0.05**	**0.08**	**0.03**	**0.06**	**9.05%**
PRODUCT 30	**0.20**	**0.01**	**0.07**	**0.08**	**0.06**	**0.05**	**0.05**	**0.12**	**0.11**	**0.09**	**8.49%**
PRODUCT 31	**0.16**	**0.09**	**0.08**	**0.04**	**0.02**	**0.12**	**0.10**	**0.17**	**0.07**	**0.14**	**9.96%**
PRODUCT 32	**0.16**	**0.15**	**0.10**	**0.10**	**0.21**	**0.00**	**0.02**	**0.16**	**0.02**	**0.08**	**9.96%**
PRODUCT 33	**0.12**	**0.03**	**0.00**	**0.02**	**0.06**	**0.04**	**0.00**	**0.04**	**0.06**	**0.53**	**9.05%**
PRODUCT 34	**0.13**	**0.15**	**0.10**	**0.10**	**0.04**	**0.01**	**0.06**	**0.11**	**0.01**	**0.01**	**7.38%**
PRODUCT 35	**0.02**	**0.06**	**0.13**	**0.02**	**0.08**	**0.15**	**0.11**	**0.13**	**0.19**	**0.04**	**9.40%**
PRODUCT 36	**0.17**	**0.05**	**0.05**	**0.01**	**0.09**	**0.03**	**0.14**	**0.14**	**0.15**	**0.11**	**9.45%**
PRODUCT 37	**0.02**	**0.04**	**0.11**	**0.10**	**0.19**	**0.02**	**0.03**	**0.21**	**0.07**	**0.04**	**8.41%**
PRODUCT 38	**0.17**	**0.04**	**0.06**	**0.06**	**0.02**	**0.10**	**0.12**	**0.14**	**0.21**	**0.02**	**9.47%**
PRODUCT 39	**0.07**	**0.10**	**0.12**	**0.11**	**0.13**	**0.10**	**0.03**	**0.01**	**0.12**	**0.04**	**8.35%**
PRODUCT 40	**0.11**	**0.01**	**0.17**	**0.04**	**0.10**	**0.11**	**0.15**	**0.09**	**0.10**	**0.04**	**9.26%**
PRODUCT 41	**0.03**	**0.05**	**0.13**	**0.03**	**0.07**	**0.09**	**0.07**	**0.12**	**0.14**	**0.10**	**8.31%**
PRODUCT 42	**0.13**	**0.01**	**0.14**	**0.09**	**0.00**	**0.18**	**0.03**	**0.05**	**0.01**	**0.00**	**6.40%**
PRODUCT 43	**0.20**	**0.01**	**0.09**	**0.23**	**0.11**	**0.05**	**0.14**	**0.01**	**0.10**	**0.09**	**10.25%**
PRODUCT 44	**0.04**	**0.10**	**0.14**	**0.04**	**0.11**	**0.06**	**0.07**	**0.14**	**0.09**	**0.12**	**9.17%**
PRODUCT 45	**0.01**	**0.09**	**0.07**	**0.26**	**0.27**	**0.08**	**0.06**	**0.04**	**0.02**	**0.05**	**9.28%**
PRODUCT 46	**0.27**	**0.05**	**0.19**	**0.22**	**0.04**	**0.03**	**0.02**	**0.04**	**0.08**	**0.04**	**9.91%**
PRODUCT 47	**0.21**	**0.07**	**0.07**	**0.07**	**0.20**	**0.01**	**0.00**	**0.07**	**0.08**	**0.07**	**8.61%**
PRODUCT 48	**0.26**	**0.10**	**0.15**	**0.12**	**0.06**	**0.08**	**0.04**	**0.02**	**0.01**	**0.06**	**8.91%**
PRODUCT 49	**0.08**	**0.04**	**0.14**	**0.03**	**0.23**	**0.05**	**0.05**	**0.08**	**0.03**	**0.16**	**8.96%**
PRODUCT 50	**0.05**	**0.02**	**0.03**	**0.01**	**0.22**	**0.03**	**0.39**	**0.02**	**0.05**	**0.07**	**8.93%**
PRODUCT 51	**0.07**	**0.03**	**0.02**	**0.05**	**0.01**	**0.09**	**0.20**	**0.13**	**0.09**	**0.12**	**8.12%**
PRODUCT 52	**0.04**	**0.32**	**0.12**	**0.10**	**0.10**	**0.06**	**0.03**	**0.03**	**0.00**	**0.07**	**8.75%**
PRODUCT 53	**0.02**	**0.09**	**0.00**	**0.18**	**0.08**	**0.12**	**0.13**	**0.06**	**0.15**	**0.08**	**9.20%**
PRODUCT 54	**0.10**	**0.12**	**0.19**	**0.01**	**0.13**	**0.04**	**0.13**	**0.03**	**0.24**	**0.00**	**9.92%**
PRODUCT 55	**0.10**	**0.03**	**0.08**	**0.00**	**0.08**	**0.02**	**0.01**	**0.14**	**0.25**	**0.08**	**7.94%**
PRODUCT 56	**0.04**	**0.02**	**0.15**	**0.35**	**0.09**	**0.13**	**0.01**	**0.07**	**0.14**	**0.02**	**10.17%**
											9.18%

4.5 Inventory management

For the analysis of the classical EOQ indicated in equation 1. The following relevant costs are considered. The cost of keeping each unit in inventory (Ch) is 5% of the selling price (price), the cost to order (Co) is $3.75 for each unit requested and the level of service that has been considered for products in classification A of 95% according to equation 6 due to the importance, they represent for the company.

$$z_{score}(0.95) = 1.644854 \tag{6}$$

Likewise, the total cost incurred in such products will be considered (Table 4), which will allow the comparison of EOQ about the forecasts generated which are considering the seasonality of the products on an annual basis. Comparing the costs incurred when using the EOQ model (Equation 8) and the seasonal forecast (Equation 9), the inventory value is 14% lower, this demonstrates the effectiveness of an adequate estimate for increasing cash flow. The assumption of using seasonal forecasts considers a weekly order that covers the demand adjusted to this period based on the projected monthly demand. To absorb any variations that may exist is also considered a safety stock (Equation 7), taking into account service level (Equation 6) and delivery time.

$$\text{SS}=(\sigma)(z)\sqrt{L} \tag{7}$$

$$TC_{EOQ} = \left(\frac{D}{Q}\right)(Co) + \left(\frac{Q}{2}\right)(Ch) + \left(\frac{Q}{2}\right)(Price) \tag{8}$$

$$TC_{FCST} = \left(\frac{D_{fcst}}{2*4_{wk}}\right)(Co) + \left(\frac{D_{fcst}}{2*4_{wk}}\right)(Ch) + \left(\frac{D_{fcst}}{2*4_{wk}}\right)(Price) \tag{9}$$

Where:

SS = Safety stock,

σ = Standard deviation within the sampled values,

L = Lead time of each product,

TC_{EOQ} = Total costs related to a classical economic order quantity considering inventory value,

D = Forecasted demand for the whole planning horizon,

Q = Economic order quantity,

Co = Ordering cost for each product,

Ch = Holding cost within planning horizon,

Price = Selling price for each product,

TC_{FCST}= Total cost associated with the proposed forecasting model,

D_{fcst}= Period specific forecasted demand.

5 Result and discussion

For the case study, it was found that traditional time series forecasting methods are not optimal due to the so variable nature of the demand in the products. Being that the closest model is the centred moving average, with an error greater than 25%, so its application is not viable because its accuracy is only reasonable (Figure 2), directly affecting the level of service sought by the company. Although 20% MAPE is considered a good result [34], for the company's indicators, this is an inadequate value that would not satisfy the needs of its customers, as well as the value of inventory in each period. On the other hand, the implementation of forecast techniques that consider the seasonality of demand offers a highly accurate forecast. Calculating demand forecast with error minimum will help meet the objectives of the company without sacrificing service level.

It is observed that despite increasing the number of orders and changing the economic lot size, the savings in terms of inventory value continue to exceed the cost of ordering material. It combined with the lack of minimum order size for most of the products and having only one supplier, favours the implementation of this improvement. Importance of apply forecast methods, ABC classification and EOQ model is demonstrated that the total costs associated can be reduced. It is crucial to complement classical models with case-specific variables, such as in this scenario, the selling price had a key role in replenishment decisions. Before this study, the cost of materials was overlooked by the company, resulting in non-healthy stock levels for products with low demand. Beginning with the ABC classification, something new for the company, stakeholders will have the capability to focus their efforts to make sure the top products are always available for their customers and, in contrast, they will be able to carefully follow up those materials that do not have an added value and decide whether it necessary to keep them in inventory.

Table 4 Total costs comparison

PRODUCT	Annual forecast (pieces)	Monthly σ (pieces)	Monthly demand (pieces)	Unit price (MXP)	SS (pieces)	Q* (pieces)	# of orders with EOQ	TC EOQ (MXP)	Monthly forecast (pieces)	TC Forecast (MXP)
PRODUCT 1	280	10.74	23	1,533.00	6	5	56	4,253.32	29	5,876.18
PRODUCT 2	268	8.97	22	1,533.00	6	5	54	4,244.32	15	3,039.40
PRODUCT 3	43	2.19	4	1,533.00	2	2	22	1,697.95	4	810.51
PRODUCT 4	52	3.89	4	1,533.00	3	2	26	1,714.84	9	1,823.64
PRODUCT 5	89	5.89	7	1,533.00	4	3	30	2,537.23	11	2,228.90
PRODUCT 6	151	7.53	13	2,173.00	5	3	50	3,627.56	25	7,175.60
PRODUCT 7	60	3.02	5	1,993.00	2	2	30	2,215.14	2	526.57
PRODUCT 8	135	5.99	11	1,945.50	4	3	45	3,247.54	19	4,883.45
PRODUCT 9	57	1.85	5	1,473.00	2	2	29	1,660.92	4	778.86
PRODUCT 10	298	5.05	25	1,071.00	6	6	50	3,576.00	28	3,967.67
PRODUCT 11	156	5.23	13	2,173.00	6	3	52	3,633.82	14	4,018.34
PRODUCT 12	54	3.61	5	2,173.00	3	2	27	2,393.77	4	1,148.10
PRODUCT 13	41	1.75	3	2,173.00	1	2	21	2,369.38	6	1,722.14
PRODUCT 14	129	6.61	11	2,173.00	4	3	43	3,600.04	28	8,036.67
PRODUCT 15	126	4.35	11	2,385.00	3	3	42	3,931.76	13	4,094.75
PRODUCT 16	100	4.27	8	2,385.00	3	2	50	2,703.74	11	3,464.79
PRODUCT 17	34	2.22	3	2,385.00	3	1	34	1,385.65	4	1,259.92
PRODUCT 18	50	1.79	4	2,385.00	1	2	25	2,609.92	3	944.94
PRODUCT 19	62	2.54	5	2,385.00	2	2	31	2,632.44	9	2,834.83
PRODUCT 20	37	1.80	3	1,993.00	2	2	19	2,171.98	2	526.57
PRODUCT 21	62	2.25	5	1,993.00	2	2	31	2,218.89	5	1,316.44
PRODUCT 22	39	1.19	3	2,185.00	1	2	20	2,378.28	5	1,443.03
PRODUCT 23	28	3.10	2	2,283.00	2	1	28	1,309.33	1	301.53
PRODUCT 24	392	19.14	33	352.50	11	12	33	2,353.85	45	2,112.91
PRODUCT 25	318	13.08	27	352.50	8	11	29	2,153.81	33	1,549.47
PRODUCT 26	209	13.69	17	352.50	8	9	23	1,760.59	21	986.02
PRODUCT 27	404	13.50	34	497.50	8	11	37	3,024.49	41	2,709.07
PRODUCT 28	105	5.74	9	617.00	4	5	21	1,706.10	16	1,309.33
PRODUCT 29	363	8.99	30	243.50	6	14	26	1,895.50	33	1,075.13
PRODUCT 30	477	7.72	40	148.50	5	21	23	1,730.20	43	862.23
PRODUCT 31	370	13.46	31	497.50	8	10	37	2,763.09	49	3,237.66
PRODUCT 32	212	5.40	18	497.50	4	8	27	2,198.84	30	1,982.24
PRODUCT 33	158	6.26	13	497.50	4	7	23	1,921.67	23	1,519.72
PRODUCT 34	185	10.71	15	497.50	6	7	26	1,936.15	21	1,387.57
PRODUCT 35	368	17.33	31	497.50	10	10	37	2,762.34	65	4,294.86
PRODUCT 36	170	6.24	14	542.50	4	7	24	2,094.26	26	1,872.23
PRODUCT 37	216	8.06	18	542.50	5	7	31	2,118.92	29	2,088.26
PRODUCT 38	134	4.88	11	542.50	3	6	22	1,800.77	19	1,368.17
PRODUCT 39	113	6.30	9	542.50	4	5	23	1,515.61	20	1,440.18
PRODUCT 40	266	14.34	22	542.50	9	8	33	2,414.06	23	1,656.21
PRODUCT 41	161	8.23	13	454.00	5	7	23	1,762.66	12	724.06
PRODUCT 42	1810	82.80	151	31.50	47	89	20	1,555.12	104	480.80
PRODUCT 43	3041	41.49	253	35.50	24	108	28	2,128.04	195	1,004.35
PRODUCT 44	192	12.11	16	320.00	7	9	21	1,599.21	11	469.35
PRODUCT 45	254	9.31	21	320.00	6	10	25	1,783.27	22	938.69
PRODUCT 46	172	6.51	14	320.00	4	9	19	1,590.87	14	597.35
PRODUCT 47	693	23.75	58	138.50	14	26	27	1,999.50	77	1,442.46
PRODUCT 48	410	13.71	34	151.00	8	19	22	1,594.33	45	917.17
PRODUCT 49	340	9.90	28	2,404.99	12	4	85	5,393.37	7	2,223.32
PRODUCT 50	1524	51.51	127	520.00	29	20	76	5,771.80	99	6,835.15
PRODUCT 51	2446	68.47	204	51.00	39	81	30	2,292.36	180	1,295.02
PRODUCT 52	1607	88.93	134	58.00	50	62	26	1,994.10	115	933.53
PRODUCT 53	2698	38.08	225	40.00	22	96	28	2,131.01	201	1,154.53
PRODUCT 54	178	7.12	15	398.00	4	8	22	1,763.01	19	1,006.12
PRODUCT 55	5261	126.84	438	133.00	142	73	72	5,391.80	351	6,320.78
PRODUCT 56	356	34.71	30	509.00	20	10	36	2,818.49	10	675.91
								139,833.03		**120,692.68**

6 Conclusions

The time series methods are applicable for products where their demand is stable, with small variations or tendencies to high or low. Nevertheless, for those products in which demand can be variable as in the case of a retail company. It is necessary to analyse the historical sales for choosing an adequate technique that achieve a MAPE less than 10%, so it is a highly reliable forecast and complementing it with the safety stock. It will allow the company to comply with its service policy of 95%, without the need to have an excess of inventory or risks of lost sales. EOQ model does not consider lower inventory costs, demand fluctuations and special-order policies similar. This model involves costs across the entire planning horizon without analysing specific periods within it, which can reduce the cash flow of the company in specific periods, by not considering those low demand in specific periods and risking having shortages in those periods where demand increases.

Therefore, an accurate forecast can reduce inventory costs in each of the periods, satisfying customer demand, by at least 14% against the classic EOQ methodology. EOQ model should apply to all products for reducing the investment in slow-moving stock and improving the inventory for those highly demanded products which can generate flexibility to embrace market complexity and meet customer expectations in terms of quicker response to spot projects. It is also expected to strengthen the company's qualification to create a partnership between professional contractors to make them choose this company as the first option in their projects due to its high service level. As a future study, it is intended to help the company to develop a strategy to reduce non-rotating inventory knowing more accurately what and when they will sell specific products. This inventory management proposal might be complemented with a marketing campaign to enhance profit results and ultimately improve cash flow.

Another important future study should be consolidated product receptions in one single receiving location to distribute to all the company branches. Instead of having individual inventories, there might be a central location to replenish the stores in a frequent basis, considering the optimisation of the distribution costs associated to this further study, which would be a new variable added to the board. Seasonal demand model must be considered to find specific products that might not fit the proposed methodology since some of them have to be ordered in minimum quantities that might exceed the forecasted demand. For these exceptions, a different inventory management technique should be studied in future research.

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SUSTAINABLE MULTIMODAL AND COMBINED TRANSPORT IN THE EUROPEAN UNION

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Abstract: The manuscript deals with the problematic of multimodal and combined transport in the European Union. Multimodal transport is an intermodal transport where most of the road in Europe is carried out by rail, inland waterway or maritime transport and each start and end of the road that is made by road is as short as possible. Road traffic is used only on short routes, e.g. for the carriage of goods to rail or sea or to pick up the goods at the place of unloading. The aim of this manuscript is to point out of the European Commission priority, that is to reducing CO_2 emissions, congestion and air pollution to improve the quality of life of European citizens. Our research is focused on state of the art of multimodal and combined transport with which it can be reduces CO_2 emissions and energy consumption per cost unit and future directions of multimodality.

1 Introduction

Intermodal transport or combined transport means the transport of goods where a lorry, trailer, semi-trailer with or without a tractor, a swap body or a transport container uses the road for the initial or final transport section and the rail, inland waterway, sea or air transport for the remaining section, where this part of the carriage exceeds 100 km as the crow flies and the start or end of the carriage is performed by road [1]:

- between the place where the goods were loaded and the nearest appropriate terminal of loading at the initial transport stage or between the nearest suitable terminal of transhipment and the place at which the goods were unloaded at the final transport stage,
- or within a radius not exceeding 150 km as the crow flies from the terminal of a national river or seaport of loading or unloading [1,2].

The European Union has created an appropriate legal framework for the transport sector to facilitate the free movement of people and goods within the Union.

Under the Agreement of Functioning of the EU, measures taken under this legal framework include:

- common rules applicable to international transport to or from a Member State or crossing the territory of one or more Member States,
- the conditions under which a carrier not established in the territory of a Member State may carry out transport operations in that Member State,
- measures to improve transport safety as well as other relevant provisions [1,3].

The common transport policy focuses not only on promoting trans-European transport networks (TEN-T) across the EU, but also on establishing a sustainable transport network that takes environmental aspects into account. The trans-European transport networks include road, inland waterways and maritime transport as well as the European high-speed rail network [4]. Cohesion policy supports the EU's transport policy by building infrastructure and funding projects in areas such as urban transport, multimodal transport and intelligent transport systems.

2 Multimodal and Combined Transportation in the European Union

In the countries of the European Union, combined transport has received significant support, particularly from an environmental point of view, as reflected in the agreements aimed at setting up international networks. Of particular importance is the European Agreement on Major International Combined Transport Routes and Related Objects, prepared by the United Nations Economic Commission for Europe in 1991, known as the AGTC – "European Agreement on Important International Combined Transport Lines and Related Installations" [2,5]. Combined transport in the rail-road system has attracted great interest, both in terms of transport economics and transport policy [3,6]. The reasons for this concern are both environmental benefits and advantages of combined transport as an integral part of the rail freight transport strategy. In the Figure 1 is presented corridors of combined transportation across the Europe.

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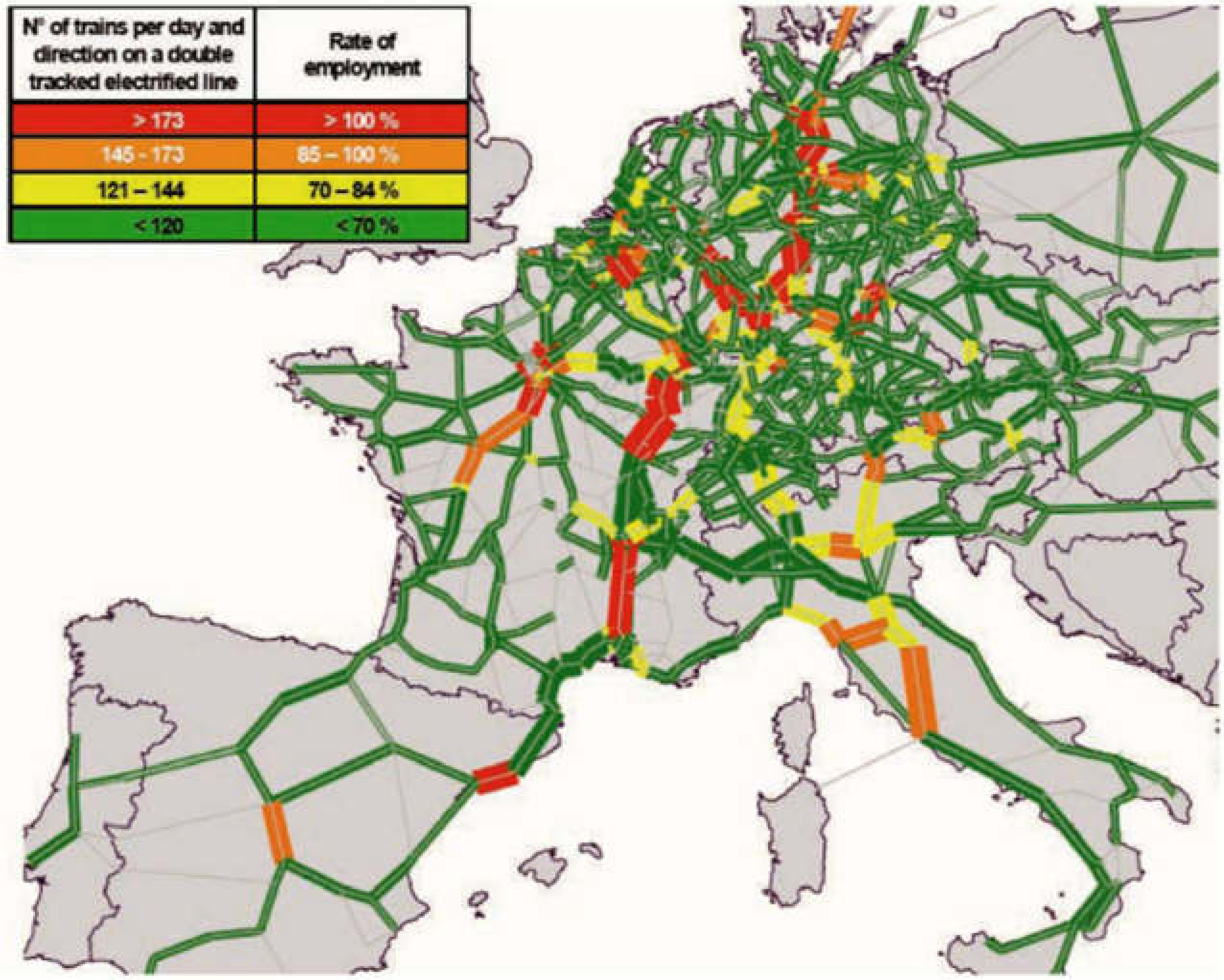

Figure 1 Corridors of combined transportation [7]

Combined transport in Europe is organized under the umbrella of the International Union of Combined Transport Society (UIRR), based in Brussels. It coordinates the co-operation of national rail and road transport operators and combined transport operators in national combined transport organizations. They are also national representatives for combined transport in the same country [7].

New economic conditions make it possible to create and operate combined transport on the principles of logistics transport chains [8]. Separate activities to date must be interconnected and complemented by various complementary activities and services (warehousing of goods, warehousing, loading and unloading, dividing and assembling of consignments, sampling, accompanying of consignments, consulting and the like) [8]. The whole intermodal transport system must be based on the needs of transporters and must fully meet their requirements. New services provided at the level of logistics chains are suitable for transporters. However, the prerequisite is the development of an overall logistics system concept, including an information system [6,9].

The evolution of logistics forms in developed European countries shows that the focus was initially on the supply of raw materials to limit and minimize stocks, on relocation from production to intermediate stores and on the supply of finished products to business partners or consumers.

3 Evaluation of multimodal and combined transportation in the European Union

The state transport system, which consists of individual types of conventional and unconventional transports, is unthinkable today without combined transport (as opposed to a combination of transports where we do not use one freight unit from the sender to the recipient when transporting by different types of means of transport) [5]. Combined transport is a transport-handling system ensuring the transport of goods in one and the same cargo unit from the consignor to the consignee as an uninterrupted chain [10]. The function of the combined transport system consists in concentrating the freight units by road to the respective terminal, where by means of efficient loading mechanisms the freight units are transferred to railway wagons or ships, followed by transport to the destination transhipment from which the transport to the recipient is ensured [6].

In principle, it is not an autonomous mode of transport, but is an efficient use of those interconnected conventional modes of transport (rail, road and waterway), which, for their comparative and systemic merits, can reliably meet the transport requirements of economic centres nationally and internationally [7]. Applying a logistic approach to transport in recent years means a gradual transition from solving individual problems (elements) of the transport process to solving the whole, i.e. of the whole transport process with the aim of its optimal solution in terms of its participants [11]. Transport is by its high share in the logistics functions of enterprises an integrating element of logistics systems, i. management of material circulation, storage, packaging, transhipment, distribution and transport. In order to manage these tasks, it seems advantageous to cumulate them in a certain area into a single place where the interrelationships between transport and other sub-systems can be managed more efficiently and faster than if they were decentralized [12]. Suitable places for such services are the points of concentration of goods flows, resp. places of important crossings of transport routes, where there is a change in the direction of goods streams, which clearly include the reloading points of the railways [10,12].

The following benefits of intermodal transport result from cooperation between the different modes of transport:

- eliminating the disadvantages of direct road transport,
- waiting at the border, since the combined transport trains are already equipped with customs at the combined transport terminals, which are recognized as border customs offices,
- driving bans on public holidays, public holidays and at night do not apply to road vehicles carrying collection and distribution from combined transport terminals,
- road tax relief for vehicles used for collection and distribution from combined transport terminals
- no need for transport permits for international road transport,
- independence from road and weather conditions [12,13].

Applying a logistic approach to transport in recent years means a gradual transition from solving individual problems (elements) of the transport process to solving the whole, i.e. of the whole transport process with the aim of its optimal solution from the perspective of its participants [8,10]. Transport is by its high share in the logistics functions of enterprises an integrating element of logistics systems, i. management of material circulation, storage, packaging, transhipment, distribution and transport.

3.1 Improving the quality of rail freight service

Multimodal and combined transport relies heavily on rail freight service, where quality is defined as a mixture of reliability, sustained average speed, uniformity of loading gauges along with maximum train length and axle loads, as well as clear and consistent traffic management rules determining priority in driving [10]. Achieving these objectives requires different types of measures for rail infrastructure managers acting as a natural monopoly and traction rail service operated under competitive conditions (open market).

- **Much more clarity** is needed to better understand the true quality of performance, consistent reporting on train departure and arrival accuracy, protocols of planned and actual average train speeds for combined transport, etc. [14]. Systematic quality monitoring should be possible for rail freight customers, such as combined transport operators and their representative organization such as the UIRR, provided that the European Commission (through the European Railway Agency) intends to intensify its rail freight quality monitoring activities [1,2,16].
- **The elimination of privileged relations** among railway undertakings and railway infrastructure managers is necessary to strengthen competition in the railway transport service. Also, the functions, responsibilities and procedures of rail infrastructure managers need to be unified throughout Europe in order to create a genuine Single European Transport Area, which can be made easier for cross-border operators to limit such opportunities by having to deal with infrastructure managers at present. The rapid and consistent implementation of the Regulation of the European rail network for competitive freight (913/2010 / EC) should further contribute to this objective [16]. A further step would be needed to achieve the necessary alignment on the established corridors (uniform invoicing, joint transport management, uniform general contract terms) [2,17].
- **Strong enforcement of existing European legislation** - such as the mutual recognition of road and rail driving licenses - as an essential element for improving the quality of rail freight service. In many cases, the incorporation of European rules into national legislation is not enough in itself to transform decades of national practice.
- **Categories of European train paths and their hierarchy**-should be established to provide the basis for well-managed train traffic on mixed lines. This priority procedure could be ensured on a fair, non-discriminatory basis, ensuring the quality of the lines for profitable rail freight [7,14].

- **Targeted complementary resources should be added at European level** to help enforce European rules and control their enforcement in their real sense in day-to-day operations. The Single European Railway Area requires a comprehensive set of common rules that are consistently applied. The amount of human resources burdened by this mandate at European level does not allow this objective to be achieved [2,5,15].

3.2 Future direction of multimodal and combined transportation

At the same time, the EU has urged, and supported by the international community (Figure 2), to significantly reduce global greenhouse gas emissions in order to keep the temperature rise caused by climate change below 2 °C. The Commission's analysis shows that, while significant reductions can be made in other sectors of the economy, the transport sector, which is an important and growing source of greenhouse gases, requires a reduction of at least 60% of greenhouse gas and CO_2 emissions by 2050 compared to 1990 [1,2,18].

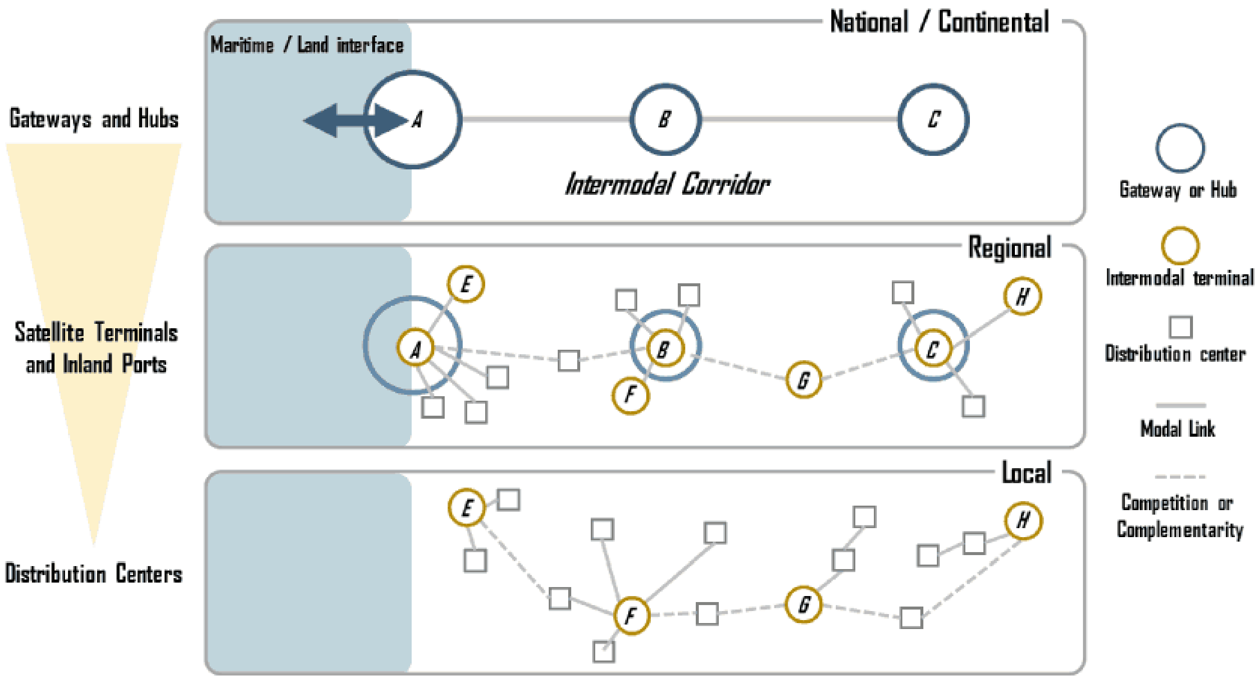

Figure 2 Description of multimodal transport system [16]

Legend:
A, B, C - gateways and hubs,
E, F, G - intermodal terminals,
H - satellite.

Generally, the multimodal and combined transport system integrates different geographical scales from the global to the local. With the development of new modal and intermodal infrastructure, countries and regions have a growing accessibility to the global market. Some modal segments can be competing or be complementary. However, the transport system is still not sustainable. From the perspective of the next 40 years, it is clear, that transport cannot develop in the same way as it has been until now. Taking the existing approach, transport dependence on oil would still be close to 90% and renewable energy sources would only at least exceed the 10% target set by 2020 [1,18].

Congestion costs will increase by about 50% by 2050 [17]. The difference in accessibility between central and peripheral areas will increase. The social costs of accidents and noise would continue to increase.

4 Conclusion

Infrastructure creates mobility. Without the support of an adequate network and greater intelligence in its use, it will not be possible to achieve major transport changes. Overall, investment in transport infrastructure has a positive impact on economic growth, generating welfare and jobs, and enhancing trade, geographical accessibility and mobility of people.

They must be designed to maximize their positive impact on economic growth and minimize their negative impact on the environment.

- more clarity, less paper reporting,

- putting into effect the competition rules in the operation of the railway infrastructure in eliminating "privileged relations",
- increased enforcement of European rules and efficient additional resources at European level,
- elimination of historical bilateral traction agreements between officials (cross-border relations),
- definition of European categories of railway lines and their hierarchy (to improve traffic management on mixed lines).

Nowadays, multimodal and combined transport are inseparable part of the transport system of developed European countries, it is not a new mode of transport, but very efficient use and interconnection of common modes of transport. It is therefore a combination the positive effects of several modes of transport, e.g. the railway transports large quantities efficiently and regularly goods over longer distances, while being greener than road transport, costly road transport is characterized by great flexibility in terms of transport time and its advantage is accessibility almost everywhere.

According to European statistics, the relationship of rail transport (including multimodal and combined transport) to the environment can be characterized in it in the sense that this is an environmentally and energy-friendly mode of transport.

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NEW TECHNOLOGIES FOR SUSTAINING DEVELOPMENT IN INFRASTRUCTURE, LOGISTICS AND CONSTRUCTION INDUSTRY

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Keywords: sustainability, infrastructure, construction industry, green roof, ecological footprint

Abstract: Infrastructure, transport and the construction industry belong to a potentially significant polluted environment. However, the current development of technologies and materials in the construction industry gives the possibility to eliminate the negative effects of transport and construction. Designing and building green buildings can significantly improve the environment and reduce the environmental footprint of transport, logistics and construction. This research discusses the issue and possibilities of new progressive technologies implemented in the construction industry for the needs of sustainable infrastructure, logistics and construction. The paper details the possibilities of green roofs, their advantages and impact not only on the construction industry, but also on infrastructure and transport in general. The aim of the paper is to specify these technologies and possibilities from the theoretical point of view.

1 Introduction

In general, the construction industry, logistics, infrastructure and transport can to a large extent pose a potential risk to environmental pollution [1]. Transport and infrastructure can have a significant negative impact on the environment [2]. Rail transport is one of the potential polluters in this area [3]. The automotive industry can also contribute to the ecological footprint. Electromobility can be one with solutions to combat it [4]. The elimination of the ecological footprint should already be considered in the urban design [5]. There are many possibilities in the construction industry to implement the so-called. green solutions. Implementing green solutions in every industry is very important [1,6]. This issue is a very sensitive topic and its importance does not need to be emphasized. This research discusses the issue and possibilities of new progressive technologies implemented in the construction industry for the needs of sustainable infrastructure, logistics and construction. The paper details the possibilities of green roofs, their advantages and impact not only on the construction industry, but also on infrastructure and transport in general. The aim of the paper is to specify these technologies and possibilities from the theoretical point of view. Infrastructure, logistics, urbanism and the construction industry have much in common. It is the solutions for the design and construction of green buildings and roofs that can be one of the solutions to achieve environmental sustainability while reducing the environmental footprint.

One of the generally accepted indicators of sustainable development is ecological footprint. Ecological footprint is an artificially created unit for measuring the impact of human activity on the planet and the environment. It determines the amount of square hectares of productive area needed to meet the needs of the population (growing food, absorbing waste, absorbing carbon dioxide emissions, etc.) [1,7].

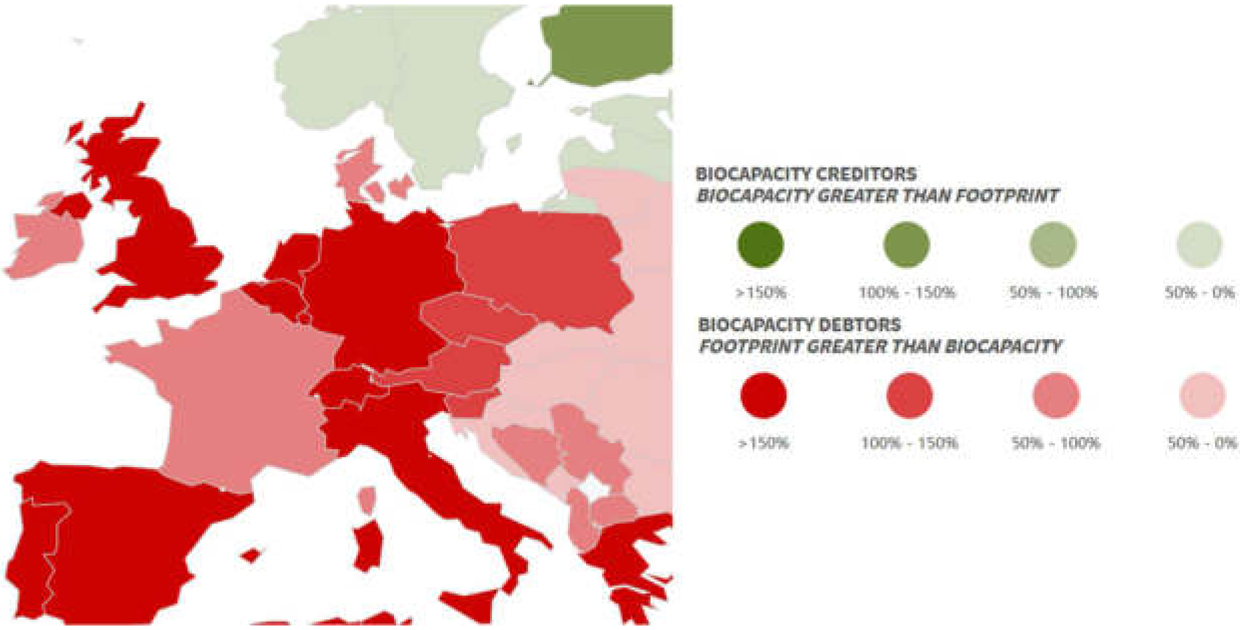

Figure 1 Ecological deficit / reserve, [7]

Of the entire productive surface of the earth, there are an average of 1.7 global hectares (gha) per person. At present, the average ecological footprint of one person has reached up to 2.8 gha, which means over 64% of the Earth's biologically productive capacity [8,9]. In the figure (Figure 1) we can observe the ecological deficit (red colour), respectively. ecological reserve (green colour) of individual states of the European Union. A national ecological deficit occurs when a given country imports biocapacity through trade, respectively. It emits carbon dioxide emissions into the atmosphere.

Data of the last measurement in 2016 (according to [7]) point to 3 gha of total biocapacity in the Slovak Republic, but the ecological footprint is 4.2 gha per person. There is an environmental deficit of 1.2 gha in Slovakia. However, this deficit has been on a downward trend since 2008 (Figure 2).

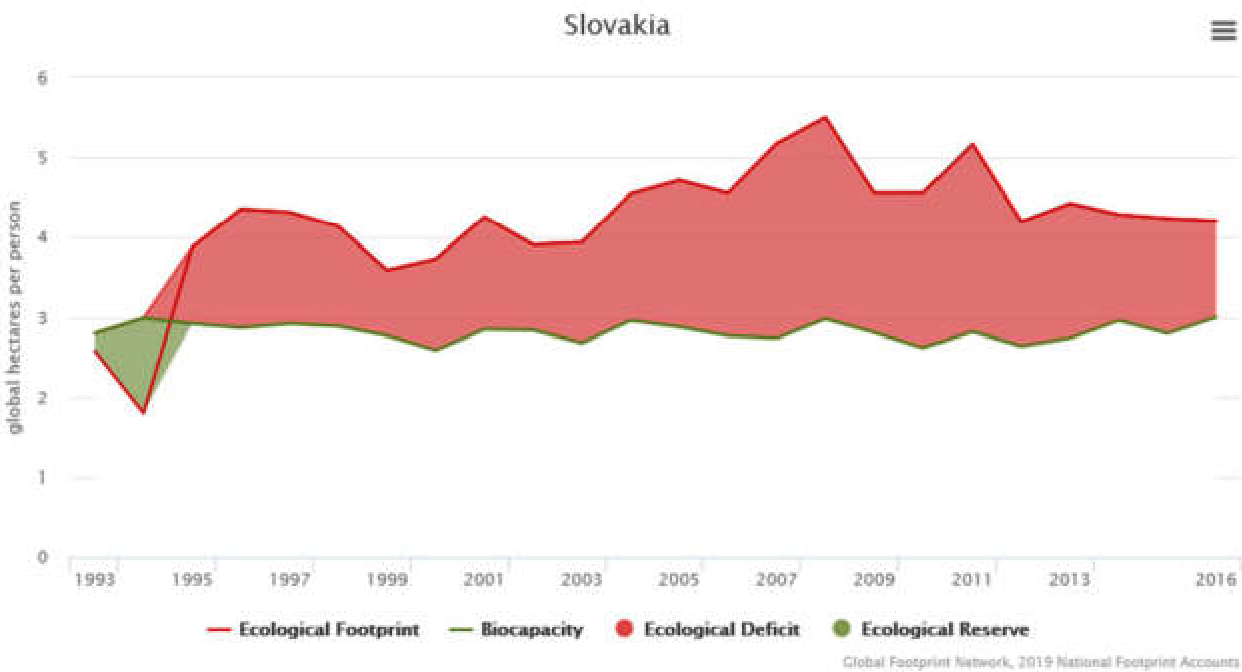

Figure 2 Slovakia - ecological deficit/reserve, [7]

In November 2018, the European Commission presented a long-term strategy to meet the targets for reducing carbon emissions in various sectors to prevent climate change, namely the Emissions Trading System for industry. According to [10], these measures aim to reduce industrial emissions by 43% compared to 2005. However, sectors such as transport, agriculture, buildings, waste management, etc. they produce almost 60% of total emissions in the European Union. The European Commission also aims to reduce these levels by 30% by 2030 compared to 2005. Another, non-important EU objective is to prevent emissions from deforestation, as forests can absorb more than 10% of EU emissions and greenhouse gases [10].

2 Green roofs, infrastructure and construction industry

Buildings are one of the largest environmental polluters. Currently, buildings spend up to 70% of electricity generated, 12% of water and produce almost 70% of all waste and more than 30% of greenhouse gas emissions [11]. This upward trend is related to the constant growth of the global population and the related urbanization and industrialization. The lawns gradually change to impermeable surfaces, roads, roofs. One of the first significant changes in grassland decline is a change in the hydrological status of the river basin, which causes changes in river flows, increased floods in cities [12], soil erosion [13], or increased pollutants in runoff [14]. The study [15] points to the link between increasing urban development and declining natural replenishment of groundwater in the area. With climate change and the occurrence of more frequent heavy rainfall, there is an increasing demand for more efficient rainwater logistics in cities, [16].

2.1 The benefits of green roofs

Designing and building green roofs, which have several benefits, is becoming one of the most advantageous solutions in solving these problems in cities:

- absorption of carbon dioxide,
- rainwater retention,
- reduction of rainwater wastewater,
- protection of the roof from UV radiation,
- protection of the roof against weathering (prolongation of the roof life),
- noise reduction inside the building,
- better thermal insulation properties of the roof,
- reducing heating and cooling costs,
- psychological and aesthetic effect,
- biodiversity creation.

The advantage of green roofs is that they are complementary to existing roofs. They consist of several layers (Figure 3): roof deck, water proofing membrane, insulation layer, root barrier, protection layer, drainage layer, filter fabric, growing media and vegetation.

Figure 3 Components of green roof, [17]

2.2 Division of green roofs

Division of green roofs according to maintenance:

- **Extensive** – They require minimal maintenance, are lightweight and inexpensive, but have a low diversity of plants that are placed in a mixture of sand, gravel, clay and peat. However, these plants are resistant to extreme climatic conditions. Maintenance is only required twice a year.
- **Semi-intensive** – using light substrates, requiring more frequent maintenance of a denser and more varied growth medium.
- **Intensive** – are similar to a traditional garden. They require regular irrigation as well as maintenance and reinforcement of the roof structure.

In the Table 1 individual characteristics of extensive, semi-intensive and intensive green roofs are listed.

Table 1 Characteristic extensive, semi-intensive and intensive green roof, [18]

Main factors	Extensive	Semi-intensive	Intensive
Vegetation	restricted selection of low growing, drought tolerant plants and hardy	grass, herbs, shrubs	trees, shrubs, herbaceous plants
Use of	ecological protection layer	designed green roof	park, garden
Substrate height	< 15 cm	15 – 50 cm	25 – 100 cm
Substrate depth	2 – 15 cm	15 – 50 cm	> 15 cm
Irrigation	no or little	periodically	regular
Weight	50 – 150 kg/m^2	120 – 200 kg/m^2	250 – 1000 kg/m^2
Available	inaccessible	partly accessible	accessible
Capacity construction	existing structures	additional structural support	additional structural support
Maintenance	extensive	periodically	intensive
Roof slope	up to 30°	flat, terrace	flat, terrace
Cost	low	medium	high

3 Environmental benefits of green roofs

3.1 Noise reduction in buildings

Last but not least, growth media are excellent sound insulators. Tests show a reduction in indoor air pollution by up to 10 dB. A classic roof reduces noise pollution by 32 dB, a green roof with a 12 cm substrate thickness by 40 dB and a green roof with a 20 cm substrate layer by up to 50 dB [19]. These results show that green roofs can be used mainly in areas with higher noise levels, such as flight halls, discos, etc.

3.2 Energy consumption reducing in buildings

In the past, green roofs were mainly used for their thermal insulation properties. Nowadays, their primary task is also to reduce the flow of energy between indoor and outdoor environments. According to a study [20], an overall annual reduction in energy consumption due to the construction of green roofs was noted by 66%. In another study [21], the authors describe that reducing the indoor temperature of a green-roofed building could reduce the cooling energy consumption by up to 8%. Articles [22-24] describe further reducing the cooling load of green-roofed buildings in Singapore, Minnesota and Toronto.

3.3 Reduce stormwater

One of the main tasks of green roofs is the retention of rainwater. The substrates either absorb rainwater or return it to the atmosphere via evapotranspiration. A study [25] has shown that through green roofs it is possible to reduce the volume of runoff rainfall by 60-100%. However, this percentage largely depends on the depth and composition of the substrate, roof slope, precipitation characteristics or climatic conditions. For example, in Germany, the authors of the study [26] reported that intensive green roofs showed a 65-85% decrease in annual rainfall runoff and a 27-81% reduction for extensive green roofs.

4 Urban air quality and green infrastructure

Today, more than half of the world's population lives in cities. Cities are constantly growing. According to [27], between 1990 and 2018, the population of medium-sized cities (cities with 1-5 million inhabitants) almost doubled worldwide, with an increase of up to 28% in these areas between 2018 and 2030, today 926 million to 1.2 billion inhabitants.

Air pollution from carbon dioxide (NO2) and other particulate matter (e.g. PM2.5) in these areas is one of the most common causes of death worldwide. According to [28], up to 3 million people worldwide die prematurely annually. On the one hand, as the standard of living increases, the demand for passenger cars is increasing, and on the other, cities must seek effective methods to reduce unwanted air pollutants and thus protect the population. The overall increase in passenger cars is estimated from 0.1 to 109 in 1960 to 1 to 109 in 2017. Also, the relative increase in the number of non-compliant diesel vehicles is another adverse factor in some countries [29,30].

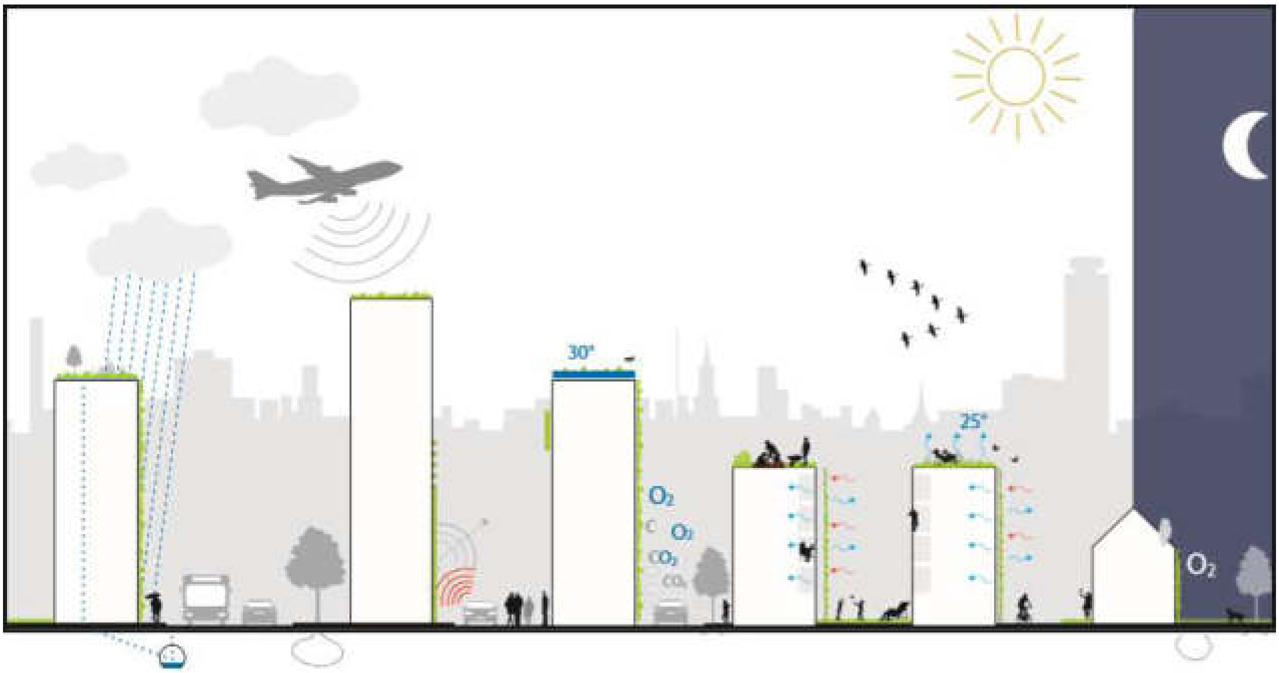

Figure 4 Benefits of green infrastructure [31]

One of the solutions to air pollution in cities is to build green infrastructure: parks, green roofs, green walls, etc. [30]. Figure 4 clearly points out the potential benefits of green infrastructure, which include, in addition to those described above, for example improving air quality, reducing the number of fine particles in the air.

Plants that are part of green roofs act as a filter for carbon dioxide, carbon monoxide, nitrogen oxides, sulphur dioxide and other harmful gases. In a study [32], the authors report that a 21-37% decrease in nitrous oxide and sulphur dioxide in the atmosphere can be observed with newly built green roofs. According to [33], some climbing plants (e.g. Hedera helix, Parthenocissus tricuspidata, etc.) planted as part of green infrastructure can bind up to 1.7 kg / m2 of fine airborne particles to their leaf surface.

However, preference for public transport, promoting environmentally friendly modes of transport (cycling, electric cars, etc.) remains the most effective way to improve air quality in cities, and to support the local economy, including the improvement of logistics and the distribution of food and materials to cities, urban logistics. freight transport, support for the domestic market and an overall change in urban transport for the sake of sustainability [34,35].

5 Conclusions

The ecological footprint of cities and densely populated areas is significantly higher than the ecological footprint of municipalities or sparsely populated areas. Thus, economically more advanced countries produce a higher percentage of emissions compared to less developed countries. With rapid population growth and rising living standards, the amount of impermeable surfaces in cities, dust particles and air pollutants, the amount of waste materials in the water, the amount of noise in cities, and vice versa, will probably increase in the future. One of the more efficient solutions that is increasingly being used is to build green infrastructure in cities and thus reduce the adverse impact of the urban climate on the population. It seems that in this economically advanced world, man as an individual does not have the opportunity to change, respectively. Reduce the percentage of air, land, water, etc. However, only the individual can begin to make changes for the benefit of the whole community and thus change the thinking, lifestyle and worldview in their surroundings. One of these, for the individual undemanding life changes, can also be the creation of a green roof on their dwelling.

Indeed, infrastructure, logistics and construction can pose a risk of increasing the negative impact on the environment. Green roofs are one of the solutions to eliminate the negative impacts of transport, logistics, infrastructure and construction.

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IRON PRODUCTION LOGISTIC ASPECTS

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Keywords: iron, ore, transport, logistics, expenses
Abstract: Pig iron production is a technologically and organizationally demanding process. A blast furnace plant consists of a great number of support processes that are necessary for the continuous operation of the given blast furnace. The iron production process involves a huge volume of input raw and other materials and manufactured products. Various transportation types are used for the given material transport. The logistic demands of individual processes often differ based on a given blast furnace plant. The conducted research included an analysis of the logistic demands of individual parts of a blast furnace plant. The possibility of utilizing various transportation types and individual application options of the selected instruments has also been assessed. The research took place under the conditions of a selected iron manufacturer in the Czech Republic. This article analyzes the key aspects of the conducted research. The research was carried out in 2018-2019. The data were processed for the logistics and production part.

1 Introduction - Production processes used for pig iron production

Blast furnace iron production is a set of many physical, chemical, mechanical and thermal processes. The actual iron production that takes place in a blast furnace is subject to properly-functioning related processes. A blast furnace plant does not only include the operation of the blast furnaces themselves, but also many preparation and auxiliary operations [1]. A general diagram of a blast furnace plant is showed as part of Figure 1. The blast furnace operation is continuous. The furnaces operate without any interruption for a period of 10-15 years [2]. In order to ensure such uninterrupted operation of a blast furnace, input raw materials have to be continuously prepared and added and pig iron needs to be tapped in regular intervals [1].

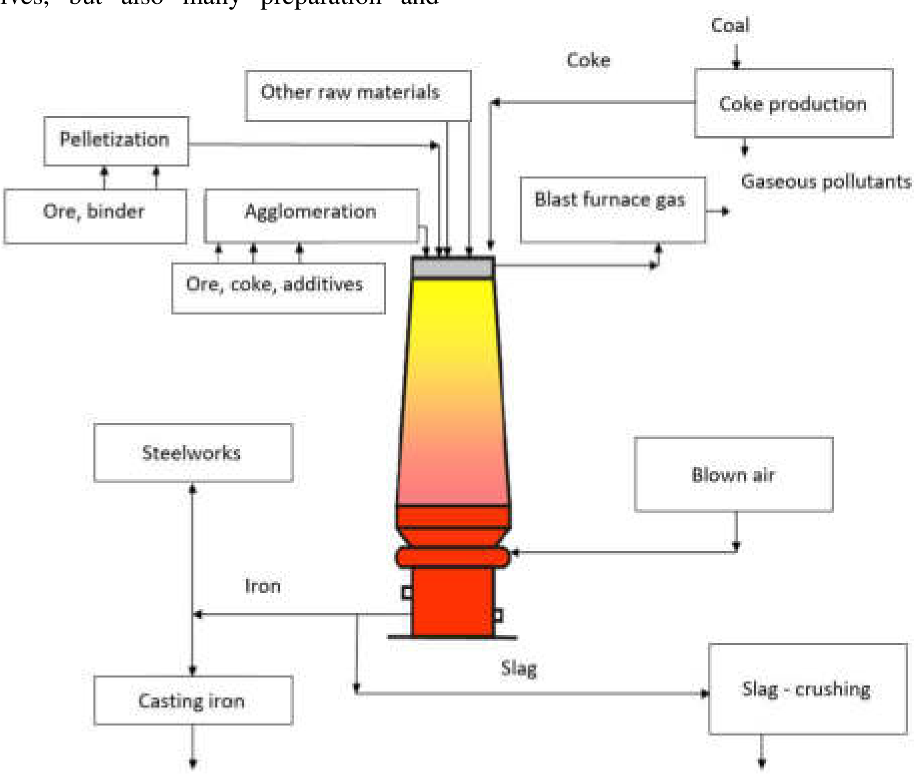

Figure 1 Blast furnace plant diagram [modified according to 2]

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Apart from the actual production technology control in the blast furnace, other operations are also fundamentally important. These operations are linked to material preparation, transport, product processing and other related activities. A separate part of a given production plant is used for processing and preparing the given metalbearing component (especially ore). Agglomeration as well as palletization procedures are used for processing and modifying raw ore materials [3].

One of the most important processes in the Czech Republic is ore sintering. One of the input raw materials used in blast furnaces are pellets. However, they are usually produced at the iron ore mining locations. They are subsequently imported to the Czech Republic in the form of ready-to-use input material. Generally speaking, agglomeration or iron ore sintering is the heating of a dust agglomeration mixture (ore part, fuel, additives) to a temperature at which the surface of the individual grain of the burden is set and the formed smelt creates liquid bridges among the grains, which, once they solidify, create a solid porous material (agglomerate). The production takes place in a continuous manner and the final agglomerate is subsequently taken to reservoirs, from which the raw material is batched to the given blast furnace. Based on their character, individual agglomeration processes can be generally divided into cold and hot segments. The cold segment is used for supplying raw materials and granularity adjustments and for averaging the chemical composition of the material (tippers, grinders, screeners, homogenization dump sites). The task of the hot segment is to produce an agglomerate of the required quality from the supplied ores, concentrates, fuel and additives. The ore sintering hot segment particularly includes daily reservoirs, mixture batchers, raw material homogenization, sintering belts and also agglomerate cooling and modifications of its granulometric composition. The primary fuel for blast furnaces is blast furnace coke. Coke can be characterized as a firm, porous and degassed residue from the coal carbonization process.

Coal thermal processing takes place at temperatures of 900-1100 °C [4] without oxygen access. Cinder-forming additives are mostly limestone-based (dolomitic limestone and dolomite).

These substances subsequently create cinder during the transition to the liquid phase for the purpose of permanently binding the acidic hypogene elements of the ore components. Harmful cinder elements from the blast furnace processes are also allocated [5].

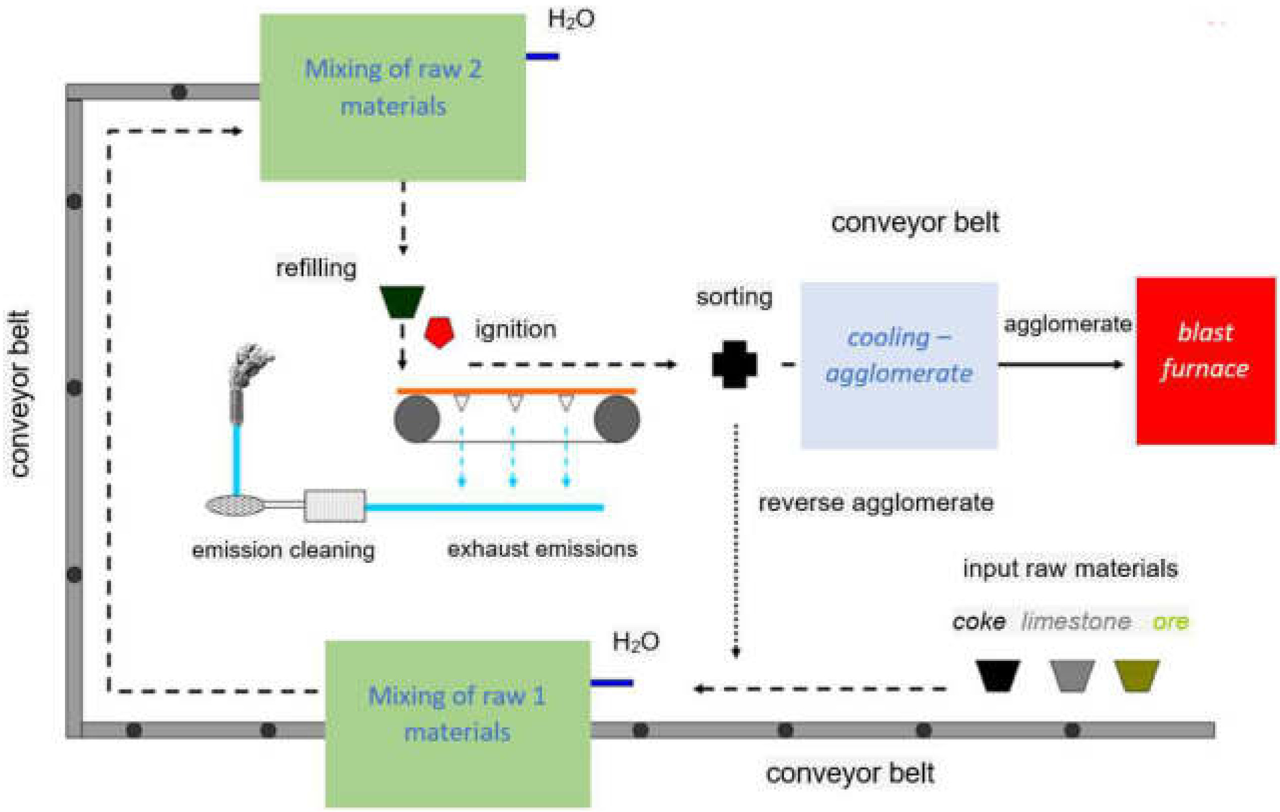

Figure 2 Agglomeration process diagram [modified according to 2]

The blast furnace profile and its size are modified pursuant to the given production technology. The bottom cylindrical part of the profile is called the hearth. Pig iron and cinder are collected here [6]. Iron and cinder are periodically tapped and discharged from the hearth. Blowpipes are installed at the upper part of the hearth.

They blow hot air and additive fuels [7]. The blown air is also moistened. The hearth is linked to a seat of a truncated cone shape with a wider top base. This shape ensures the necessary diversion of glowing gas currents from the oxidation areas from the furnace lining, which would otherwise become prematurely damaged [8]. The gradual crossing of the seat to the shaft in ensured by a belly. The most voluminous part of a blast furnace is a shaft in the shape of a truncated cone or two truncated cones. The shaft is used for preheating raw materials, the decomposition of carbonates and indirect reduction [9]. The upper part of the blast furnace is called the throat. It is used for filling the furnace with burden and for discharging throat gas from the furnace. Output products and waste (agglomeration dust, blast furnace flue-dust emissions, blast furnace sediments and cinder) are also processed. Waste processing is based on the possibilities of its further utilization in other industrial areas, but also on its possible repeated use for iron production. Waste production and processing are also demanding due to its quantity. The volume of cinder, for example, amounts to 200-400 kg [10] per one ton of the produced pig iron.

From the perspective of logistic processes, a significant part of a blast furnace plant is used for agglomeration [11]. This is where iron ore is being sintered while using coke and basic additives. Figure 2 shows the main parts of the entire process. As part of the first step, the input raw material is batched onto the conveyor belt. From the perspective of the entire process, this type of transport represents a key operation since it allows for transporting a huge quantity of material. The input raw materials are then stirred in homogenization drums, where they are also moisturized. This mixture is subsequently batched on the sintering transportation belt, onto which the mixture is processed thermally. Once the processing is completed, the agglomerate is modified from the granulometric point of view. The agglomerate is then transported to the blast furnace reservoirs. All of this is also implemented using conveyor belts. From the agglomerate production perspective, conveyor belt transport is thus a key requirement and it is very difficult to substitute it with any other form of transportation.

2 Logistics of metallurgical products

Steel products are manufactured in huge volumes. Their transport to end customers represents a significant logistics problem [12]. Their production in the Czech Republic amounts to millions of tons in the form of several thousand metallurgical product items (in relation to chemical analyses, thermal processing, shapes, dimensions or possible surface treatments). The consumers of metallurgical products can be from several areas [13]. Some of the most important ones include the construction industry, mechanical engineering and the automotive industry. When it comes to the character of individual deliveries, we can identify two possibilities. The first one can be characterized as regular and continuous deliveries of a large number of metallurgical materials for mechanical engineering companies, construction projects and the automotive industry. The other possibility is related to deliveries to a network of warehouse businesses that provide distribution for certain areas (regions) [14]. When it comes to direct deliveries from metallurgical companies to consumers (companies), the whole process is usually implemented without any other intermediaries. In the other case, the deliveries are supplied to a wide range of customers from various areas via wholesale networks. In this case, the volume of the supplied goods can be of a small to medium volume. These customers cannot satisfy their needs for the given metallurgical material directly from metallurgical companies, where such requirements would accumulate [15]. From the point of view of the planning of metallurgical campaigns and production capacities, this principle is not possible from the technological and cost perspective. Due to these facts, the rolling campaigns have been getting gradually shorter. In comparison with blast furnace production, they allow for more individual control. The sales system of metallurgical products can be classified pursuant to the following structure [16]:

- Final sellers to end customers (minimal supplies),
- Regional warehouse centres,
- Local warehouse shops (complete assortment of metallurgical materials).

The demand for individual steel product types (number of sales, size of the orders, sale regularity) is also monitored in detail these days. Individual business areas behave as relatively stabilized customers, provided a certain minimal limit, determined by a given set of customers, is reached. That is why the consumption prognoses for such areas are very accurate. Consumption fluctuations are resolved by the mutual cooperation of local warehouses, making sure there is a sufficient volume of all metallurgical products in the given area. Cooperation among individual warehouses can also correct errors in the given future consumption prognoses. Local warehouses form the most important nodes of the entire distribution network. They represent the main location for statistic assessments of the steel consumption pursuant to individual products.

3 Used transport types and their use in the metallurgical industry

Transport can be understood as a set of all activities used for moving means of transportation along transport routes and for moving material or people by the means of transportation or devices. Transport represents activities and technical means designated for transporting people and cargo [17]. Transport logistics then coordinate, synchronize and optimize the movement of goods and raw materials within the transportation network, utilizing one or several transport types. The main objective of transport logistics is not only primarily to make transport easier, but, most of all, to flexibly and economically satisfy the needs of individual customers. We can then perceive customers not only as external users of the provided services, but also as an internal, company material consumption within different production centers [13]. A reduction of the extent of the movement of individual means of transportation, necessary for implementing a certain material logistic chain, is also achieved by making the corresponding transports easier. This is due to the main principle of the transport logistics, which strives to minimize all purposeless physical movement and material flows when moving material, raw materials or finished products. The end goal of this process is to not only reduce the cost, but also the corresponding environmental burden, while improving transport quality and reliability.

Considering the volume of the transported material and raw material, metallurgical production is an extremely demanding process. Iron manufacturers in the Czech Republic produce over 5 million tons of crude metal annually. When it comes to ore raw materials, one needs 1900 to 2100 kg of the ore component for the production of one ton of pig iron. The volume of coke (which is used as a dominant source of thermal energy) needed for one ton of the produced pig iron, amounts to 300-400 tons [18]. The needed volume of the basic additives mostly depends on the alkalinity or acidity of the ore component. Iron manufacturers in the Czech Republic use mostly acidic ore raw material, which require the use of a greater quantity of the basic additives. The volume of the used alkalis can then be between 300 and 400 kg [19] per one ton of the produced iron. The total volume of the used raw materials that pass through a metallurgical company in a single year amount to several million tons. This huge quantity then results in great demands on the transport and optimization of all related logistic processes.

4 Basic characteristics of individual cargo transport types

The current logistic processes allow for utilizing a wide spectrum of the transport types. Each transport type has several specifics and limitations from the perspective of the transported medium, transport cost or suitable transport distance. Some of the basic transport types include road, railroad, water, pipeline, aerial, conveyor or funicular transports [13].

These transport types can mutually complement one another and can be used in a sequence or simultaneously. We can then call it combined transport (the most common scenario is railroad – road, truck transport). A basic condition of transport efficiency is the requirement that the implementation of the given moving consumes the corresponding use value [20]. Incompliance with this condition results in losses that are equal to the given moving cost. Moreover, should a given shipment not be used at all, additional losses are incurred amounting to the production cost of the unused values. We can evaluate transports based on several key criteria. Some of the main ones include transport performance, transport time, transport cost, transport frequency, network availability, flexibility, reliability and also environmental consequences. Individual customer requirements also play an important role when it comes to the distribution of metallurgical products. Apart from other things, such requirements result in a higher transport frequency or various weights of the transported cargo.

The following are the key transport types for metallurgical processes:

- road,
- railroad,
- pipeline,
- conveyor.

Road transport is irreplaceable when it comes to speed and operability, however, it has a negative impact on the environment caused by exhaust gases, noise and vibrations [21]. The advantages of this transport type include a dense network of roads, house-to-house transport, high flexibility, adjustability to given delivery times, time savings, shorter downtime and shorter waiting times [13]. Road (truck) transport in the area of metallurgical production is particularly used for transporting metallurgical products and semi-finished products, such as ingot slabs, sheet metal, belts, fired products, etc. Some of the main road transport disadvantages include harmful impacts on the environment, limited transported volumes by a single vehicle, limited loading ability or congestion. The share of the loads transported on the road in the Czech Republic is the highest among all transport types and the share keeps increasing. This stipulation applies to metallurgical products as well.

The second most important transport type from the metallurgical production perspective is railroad transport. This transport field is suitable for transporting greater cargo volumes for longer distances. Its advantages include the possibility to transport very heavy cargo shipments, independence on particular road traffic intensity, precise timetables, low costs for long distances and high material loads. In the metallurgical production field, railroad transport can be used for two large areas [22]. The first one applies to the transport of metallurgical semi-finished products for long distances. Another option is the transport of large volumes of input raw materials, such as ore, coal and alkaline additives. When it comes to ores, railroad transport is really the only transport option due to the used ore volumes and distances from individual ore deposits, provided we do not take into account ores from other continents, such as Australia or South and North America. Disadvantages of railroad transport especially include its limited shunting and maneuvering ability, the impossibility to transport cargos directly from one company to another, the dependability on timetables and smaller flexibility.

Pipeline transports in the context of metallurgical production can be perceived to be rather secondary. When it comes to pipeline transport, transportation containers, transport means and transport routes merge into a single unit. This transport field is very specific. It is used for transporting liquids, gases and sometimes also chemicals for long distances [13]. The utilization of pipeline transport as a part of the blast furnace process can be perceived to be specific. It mostly involves the transport of gases and combustion products that occur during the related production processes. Nevertheless, considering the further use and processing of these blast furnace products, pipeline transport represents a significant element. Some of the advantages of pipeline transport include reliability and safety, minimal pollution threats and continuous operation. As for disadvantages, we can mention the high financial cost of building such systems and limitations from the perspective of the transported medium.

Conveyor transport represents the most important transport type on the premises of blast furnace plants. This transport type is used for transporting ore raw materials and as a part of their processing, and also as a part of the agglomeration process, the transport of input raw materials to individual reservoirs and other processes. Conveyor transport allows for transporting huge volumes of material used in blast furnaces. We can generally say that this is the fundamental benefit of conveyor transport, which provides high performance and allows for transporting up to 6000 tons of material per hour. Due to significant acquisition expenses, which quickly increase with increased capacity, conveyor transport is particularly suitable for shorter distances. However, when transporting large volumes of raw materials, it can be economical even for longer distances (several kilometers). Its use is significant for the processes that use large volumes of input raw materials (Table 1).

Table 1 Assessment of the use of individual transport types for metallurgical processes

Transport type	Usability	Usage – in the plant / outside the plant	Character	Importance for blast furnace plants
Road	Yes	Outside the plant	Product transport to customers	7
Railroad	Yes	Outside the plant	Transport of raw materials	9
Water	No	-	-	0
Pipeline	Yes	In the plant	Transport of gaseous materials	8
Aerial	No	-	-	0
Conveyor	Yes	In the plant	Transport of input raw materials	10
Funicular	No	-	-	0

5 Characteristics of the potentially usable methods

The logistic tools and methods that are used these days are often linked to lean production principles. It is generally given by the character of the individual logistic objectives, which are, due to their nature, tightly related to the process of increasing the process efficiency [23]. Lean production and its principles cannot be understood as an exactly defined and closed system. As a part of this philosophy, several methods and instruments can be applied and their implementation manner can vary. Lean production implementation is then most often a reaction to a certain type of problem at a given company. That is why, when introducing the lean production principles, a procedure that is based on an initial audit of the lean production main parameters is often recommended. The values of selected indicators can be set as part of such a procedure [24]. Many lean production instruments originally came from the automotive industry. However, as these principles have been gradually developing and expanding to other industrial areas, other methods and instruments have been added and used. That is why it is not currently possible to provide a complete and comprehensive list of all the used methods since they are being continuously amended and modified. Nevertheless, some of the typical and frequently used lean production instruments include:

- TPM
- 5S – good management principles,
- Visual control,
- Team problem solutions,
- Management of bottleneck locations,
- Lean administration,
- Kaizen,
- Poka – Yoke,
- Jidoka,
- Heijunka,
- Kanban,
- Genchi genbutsu,
- SMED
- Multicriterial problem solutions.

Metallurgical production is quite specific and very different from large-series car production. Despite of that, some of the aforementioned methods and instruments can be successfully used for it as well. Table 2 shows selected methods that have been successfully used outside of the automotive industry and the possibilities of their application in metallurgical production.

Table 2 Selected lean production tools and their use

Transport	Usability	Area
TPM	Yes	Mainly secondary metallurgy
5S	Yes	All production areas
Kaizen	Yes	Production as well as nonproduction spheres
Lean administration	Yes	Administrative processes
Poka – Yoke	Limited	Selected segments, especially linked to improving safety
SMED	Limited	Mainly secondary metallurgy
Multicriterial evaluations	Yes	Supporting managerial decisions

The tools for supporting managerial decisions are especially universal [25]. Metallurgical processes are very demanding from the perspective of precise assessments of raw material quality, processes and individual activities. The quality of input raw materials fundamentally influences the blast furnace process with regard to individual ore components, fuel or alkaline additives. The problem of selecting a suitable contractor is created by a large number of the monitored criteria. A typical example can be the selection process of suppliers of basic additives. Completely different criteria can all play a role here and it is difficult to synthetize them into a single indicator. In order to find a suitable variant, it is very convenient to use a system that is based on a multidimensional base, which allows for considering multiple relevant characteristics. The criteria can be of a chemical, physical, logistic or economic character. Table 3 shows the selected criteria for assessing basic raw materials. Iron manufacturers cooperate with suppliers with many countries. They often need to adopt decisions related to the selection of suitable raw materials.

As part of the project solution, the quality of three types (suppliers) of the basic raw materials (dolomite – $CaCO_3$) was assessed. Four key criteria were selected for the assessment: basicity, price, storage volume and lumpiness. Based on the character of the stated criteria, it is clear that they represent quite different factors. It is thus very convenient to use multicriterial decision-making tools for assessing these data. The assessed criteria are of a different character, but also of a different significance. Basicity is a key criterion for alkaline additives since it expresses the share of alkaline and acidic components. The second criterion is the price of the basic raw material. Input raw material expenses fundamentally influence the final price of the given produced metal. The third criterion is the storage volume that is immediately available from a supplier. Blast furnace production is of a continuous character and it is thus important to make sure that all the related raw materials are operatively available. The last criterion applies to lumpiness. It tells us how homogenous given material is from the granulometric perspective.

Table 3 Dolomite criteria from potential suppliers

Criteria		Dolomite suppliers		
		Poland	Ukraine	Czech Republic
K_1	Basicity (%)	4.1	3.7	3.5
K_2	Cena ($)	20.1	18.8	19.6
K_3	Storage volume (t)	2,500	4,500	1,800
K_4	Lumpiness (%)	75	74	81

To compare dolomite suppliers from Poland, Ukraine and the Czech Republic, the method that assesses distances from a given fictious alternative was used. The method is based on determining the Euclidean distance. All the criteria values are compared with the best alternative and the final assessment is formed by a synthesis of all the monitored criteria. The fictious alternative then represents an alternative, in which the values of all the criteria are ideal [26, 27]. Formulas (1) and (2) are used for calculating the ideal alternative.

$$D_j = \sqrt{d_j} \quad (1)$$

$$d_j = \sum_{i=1}^{n} v_i \times \left(\frac{x_i^* - x_{ij}}{x_i^* - x_i^0} \right)^2 \quad (2)$$

Where:

D_j - distance from the ideal variant,
x_i^* - the length of action,
x_{ij} - the mean width of the elongated bar,
x_i^0 - the mean width of the elongated bar,
v_i - the weight of the criteria.

First, each criterion was assigned its respective weight. This weight represents the significance and importance of each criterion. The weight was determined by means of a binomial comparison of individual criteria. The determined values are then based on the executed pair decisions. Table 4, in which the distances from the fictitious alternatives are determined, also presents the weights of all the criteria (column v_i).

Table 4 Determining the ideal alternative

Criteria		v_i	x_i^*	x_i^0	d_{ij}		
					Poland	Ukraine	Czech Republic
K_1	Basicity (%)	0.450	4.1	3.5	0	0.200	0.450
K_2	Price ($)	0.250	18.8	20.1	0.250	0	0.095
K_3	Storage volume (t)	0.100	4500	1800	0.055	0	0.100
K_4	Lumpiness ($)	0.200	81	74	0.147	0.200	0
				$\sum$	0.452	0.400	0.645
				D_j	0.672	0.632	0.803
				Sequence	2.	1.	3.

The determined distance from the fictitious alternative then basically represents the sum of the deviances of individual criteria from the best alternative [28]. Its values for the basic raw materials from Poland, Ukraine and the Czech Republic were calculated using formulas 1 and 2. Based on the used evaluation principle, the lower the value, the more suitable the alternative. The distance from the fictitious alternative is shown in Table 4 in row D_j. Based on this value, we can assess the quality of the given basic raw material from the monitored suppliers. Pursuant to the values of individual criteria, we can sort the monitored suppliers in a descending order in the following manner: 1st Ukraine, 2nd Poland, 3rd Czech Republic. The determined assessment, applied using a multicriterial decision-making process, can form a basis for a potential managerial decision when selecting a supplier. Due to its universality, the applied method can be used for a wide spectrum of processes.

6 Assessment and conclusion

Iron production is a technologically demanding and complex process. A huge volume of raw materials is transported within the given metallurgical plant. Some of the greatest demands are particularly put on the efficiency of logistic processes. From the iron ore sintering perspective, the key transport type is represented by conveyor belts. They enable the delivery of input raw materials, material transport during the sintering process and also material transport to the given blast furnace. From among the other transport types, road, railroad and pipeline transports represent the important ones for metallurgical processes. Truck transport represents a key transport type in the area of the distribution of metallurgical products and semi-finished products to customers or intermediate warehouses. Railroad transport provides, apart from other things, transportation of all relevant input raw materials. It is also used for transporting metallurgical products over long distances. As part of the conducted research, we also examined the use of logistic tools based on the lean production principles in metallurgical processes. Despite the fact that these tools and methods were primarily used in other production systems, they can also be applied in the metallurgical industry. Apart from the traditional methods, such as 5S or Kaizen, exact logistic tools for supporting the managerial decision-making processes can be also used. As part of the implemented project, multicriterial decision-making methods were used for comparing the basic raw materials. The conducted assessment allows for quantifying categorically different criteria. It also offers the possibility of comparisons in the form of a single indicator. Several traditional logistic methods and tools can be used not only in the area of the production process itself, but also in the area of managerial decisions.

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