DOCTORAL DISSERTATION

THESIS BOOKLET



Budapest

BGE

# DESIGN OF A SIMULATION MODEL FOR THE EFFECTIVE REORGANIZATION OF LOGISTICS PROCESSES RELATED TO ENTERPRISES

DOCTORAL DISSERTATION

THESIS BOOKLET



Budapest

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# BACKGROUND TO THE WORK

## The importance of the topic

Due to the turbulent market environment and the acceleration of economic and social processes, more and more fierce market competition has been developed in recent decades. In many cases, companies are no longer able to achieve a significant competitive advantage in the field of product development (for instance, with regard to less complex products), therefore corporate efficiency is increasingly appreciated. (Tóth – Kálmán, 2020) Thanks to this, logistics research has also gained more and more prominence in recent years, an important dimension of which is the efficiency increase of the transport processes.

Within the narrower topic, the simulation of everyday logistics processes based on data within the company was chosen. Despite the fact that we are talking about systems with multiple factors, which are often difficult to predict, it is still worth paying special attention to their simulation, since if we learn about these hindering factors, it can give any company a great competitive advantage. The topic is significant not only from a scientific point of view or from the point of view of market competition, but also because of its wide range of usability. It is important to mention that effective logistics planning is not only typical for large companies, but is also an important factor in the market of SMEs. Despite this, it is unfortunately a common experience that smaller businesses or enterprises do not take the effective planning of their logistics background into account, or, as the case may be, they do not have the means to implement it. Starting from this, we wanted to create a solution with the help of the research that can not only help to understand the logistics processes at the level of SMEs, but can also make their operations more efficient. (Regardless of the size and resources of the business). (Pató – Herczeg, 2020; Moon – Lee - Lai, 2017; Shu et al. 2006; Sarkar et al., 2021)

I examined the topic among enterprises of Zala County; the reason for which, in addition to the availability of data, was that many logistical developments have taken place in the county in the recent period. The most significant of these were the test track in Zalaegerszeg, and roads R76 and M70. The importance of logistics, by the way, was outstanding in the area of the county even before the development began, being connected with a significant material flow, so all in all, the research goals can be particularly significant in the life of the county as well. (Szabó – Szabó – Gubán, 2020, pp. 66-77.)

## The aim of the research

Everyday logistics processes, just like the main processes of the supply chain, form a multi-factor system that can be said to be very complex. These systems are typically influenced by the given production technology, the availability of infrastructure, traffic and even the weather and other ad hoc factors. It can be said that there has already been a certain level of research with regard to the simulation of the entire supply chain, but the processes within the enterprises have remained unknown for the time being. (Bohács - Kovács - Rinkács, 2016) (By processes within enterprises, we mean that we only examined the order/delivery decisions of the given company, in contrast to the entire supply chain, where it is a process that affects several businesses.) Accordingly, the research first examined the question of whether the previously mentioned factors caused delays in everyday logistics starting from the processes within the company, and if so, what their volume was, and to what extent they led to corporate dissatisfaction (how satisfied the companies were with their own logistics processes in terms of delays).

- *Goal 1: To get acquainted with the efficiency of Zala County's logistics processes, the extent and significance of possible delivery delays. Defining the variables required for model building.*
- *Goal 2: Examination of the satisfaction of enterprises in Zala County with their logistics processes.*

After examining the basic problems and their extent, the next main area of the research was the structural examination of the capabilities of the county enterprises, their logistical problems, the damages resulting thereof, and their potential solution needs. In addition to the structure of the model, it was also of great importance to learn about the use of the supporting software and, specifically, its effectiveness in the case of local enterprises. It has already been mentioned that, despite the fact that we could come across some kind of software solution (e.g. ERP systems) more and more often even at the SME level, the use of these tools in the field of everyday logistics was not efficient at all. It was a common experience that smaller enterprises use just a specific function (e.g. invoicing) of the software, while inventory, stock tracking and production were solved somehow differently - even in an analogue way. An important goal of the research was not only to get a realistic picture of the use of the software and the IT support of logistics processes at the local level, but also to learn about the effects of the use of such tools. An important question was how the improper use appeared in practice. How much did local enterprises perceive from possible damages resulting from inappropriate use? When they perceived logistical problems, what solution needs did they have? The examination of these questions was largely related to the creation of the foundations of simulation and decision support software, as these aspects determined whether there was any realistic chance at all of re-designing logistics processes at a local level. Overall, my goal in the second phase of the research was to get to know the logistics processes at the system level, during which I wanted to get a picture of how a new logistics software could be applied even in reality. (Impedovo et. al., 2023.)

– *Goal 3: Structural level examination of the problems of logistics processes in Zala County, the damages resulting thereof, and the responses thereto.*

The third priority area of the research was the examination of the variables that affected logistics processes; using a practical example, we examined what negative factors (namely: traffic, weather, infrastructure, technology, ad hoc problems) could affect an order placed at a given time/period. Related to this, another question was whether it was possible to create a model that may give recommendations with the help of simulation regarding which periods should have been avoided in terms of purchasing. In order to be able to carry out the simulation for the processes within the company, it was essential to learn about the behaviour of the individual hindering factors and, above all, their weight in the logistics system. The problem and the answer could be summed up as that since the road networks were becoming more and more congested, and the search for new delivery routes no longer led to results, therefore, we were trying to create the foundations of such a decision support application that can give recommendations on when it was worth starting/scheduling our orders. (Gubán – Kovács – Kot, 2017; Mridha et al., 2023; Gkountani – Tsoulfas – Mouzakitis, 2022)

– *Goal 4: Construction of a special logistics model and then its simulation solution, creating the foundations of a decision support software.*

# APPLIED METHODS

## The train of thought of the research

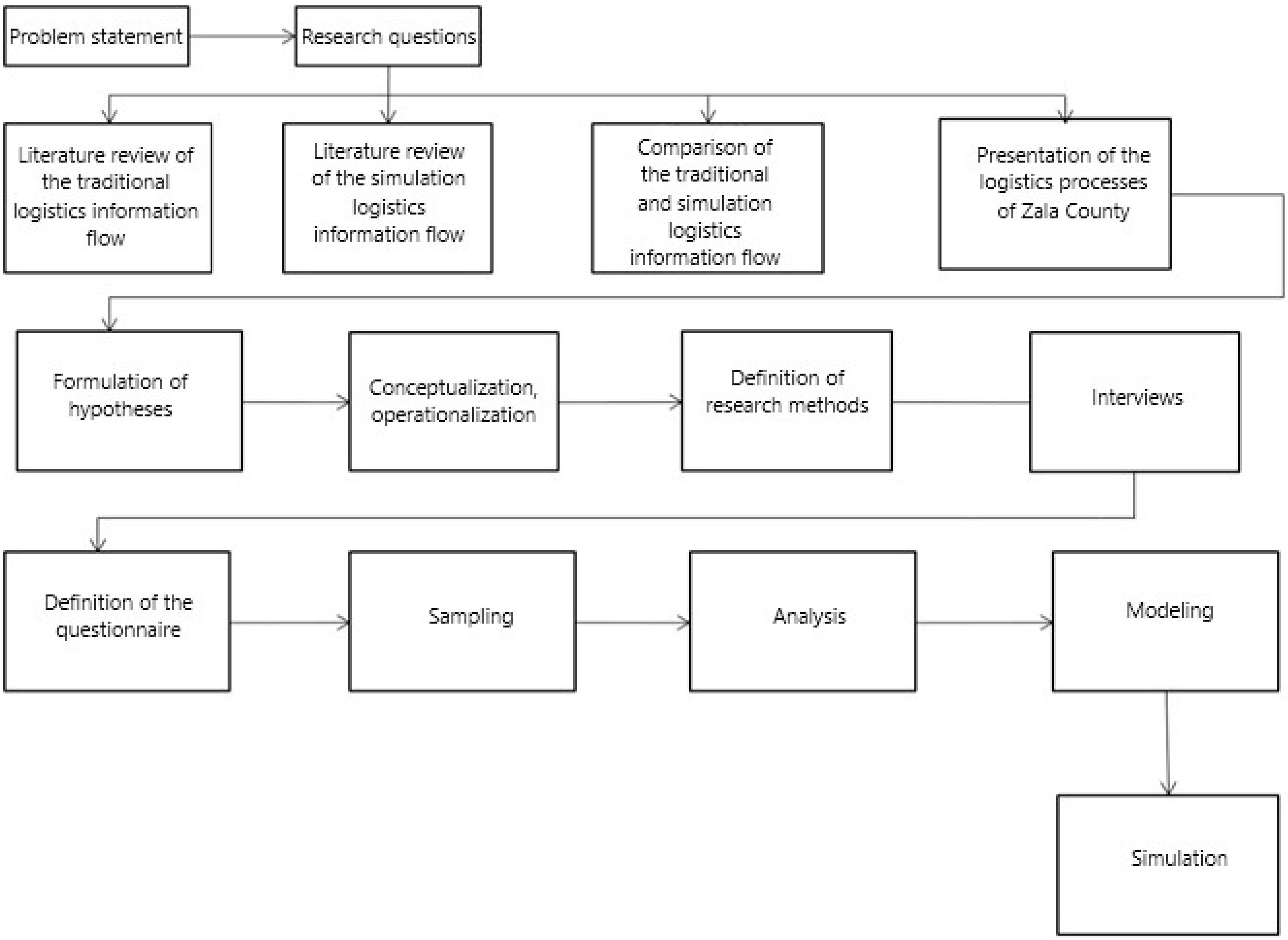
In the context of research theory, the dissertation mostly moved on the border between constructivism and realism. Certain elements of the dissertation were closer to constructivism, since we basically examined a local reality, about which we cannot unequivocally state whether it pointed towards generalization. In addition, it must also be accepted that I actively - reflexively - participated in certain additional research events (e.g. interviews) in the environment under investigation. Despite all of this, however, **realism** is the paradigm in which the research could be mostly interpreted. Despite the fact that I examined a local reality and participated in the research in a reflexive way, and if we carried out an infinite number of experiments, we would find such a case where the simulation would not work, in the vast majority of cases, however, the outlined research model and its solution would be true. Based on this, a model was created, the solution of which is **likely to be true**, and would provide the same result in the vast majority of cases. The research chose a methodology corresponding to the paradigm, which therefore contained a mixture of qualitative and quantitative methods. (Desphande, 1983; Kása, 2011)

## Data collection and forms of processing

Since we had relatively little data regarding the simulation of the material flow in terms of the entire topic, I continuously updated the structure of the study through the formulated research questions during the conduct of the research. I planned the implementation of the research using Earl Babbie's methodology (Babbie, 2008). After raising the problem and formulating the research questions, I got to know the relevant literature, which provided additional help in setting up the hypotheses. I continued to verify these with conceptualization and operationalization, and finally I defined the specific research methods. (Saunders et al., 2009.)

First, I introduced the operation of logistics systems and the literature thereof, since this was the basic environment in which the proper research topic was situated. After that, I examined the results of the simulation research so far, which I placed back into a system with which I could compare the static (ERP, MRP systems) and dynamic (simulation) solutions of the logistics information flow. After that, based on the received model, I conducted interviews, based on which I created the questionnaire. In this way I could compare the results of the questionnaire survey with the results of previous research and the existing practical solutions. After the sampling, I performed an analysis on the obtained empirical data, I concluded the dissertation with the creation of the model, the simulation, and the presentation of the results obtained in this way. (Horváth - Mitev, 2015; Mourtzis, 2020)

1. Figure: **The process of the research**




[Source: own source]

## Structure of the dissertation

In the first part of the dissertation, the broader problem raising was explained, the parts of which included the theme suggestion, the location in the scientific field, the environment of the research, and the course of the planned implementation, as well. I formulated the main goals of the research in this section, which goals were consistent with the problem originally raised. When defining the goals, the specific research questions were also formulated, and I partially presented the territorial delimitation, too.

In the next, larger part of the dissertation, the literature of the narrower topic was explained. In doing so, not only the literature necessary for the understanding of the research topic was presented, but I also put great emphasis on the comparative analysis. Within this, I presented the latest trends in logistics support software, which I compared with the earlier, more classic approach. Based on the results, I identified predictive and stock tracking approaches, in terms of which the present research clearly belongs to the former (predictive software support).

In the third stage of the dissertation, I outlined the tools I used for primary data collection, that is, the forms of data collection and processing. Regarding the research methodology, I chose a mixed research design based on both qualitative and quantitative elements, as I have already partially explained it.

In the final part of the research, I analysed the data obtained, on the basis of which I described the theoretical results. I presented the theses accordingly in this part, as well as summarized all the scientific results of the research, and made suggestions based on them.

# RESULTS

In terms of the results, it can be said that the vast majority of my initial assumptions led to a definite result. We obtained verified results in three cases out of the four main goals defined in advance, while in the case of the remaining one, certain aspects of the question require further investigation. In connection with the main result (creating the foundations of the decision support software), it can be said that the guiding principle has been defined, however, additional dimensions and areas are still necessary to be examined, but the examination of these is beyond the scope of the dissertation.

## Theses

**THESIS 1 – Most of the enterprises in Zala County are dissatisfied with the logistics processes, which therefore need to be redesigned.**

In addition to the implementation of the simulation, I put great emphasis on the mapping of the county's logistics processes, on the understanding of the potential problem sources, and on determining the possible use of the simulation. Within this, one of the first tasks was to examine the satisfaction of the county's enterprises with their own logistics processes, because this was the basis for determining whether certain processes needed to be redesigned at all. Regarding the results, only 29 of the 147 surveyed enterprises answered that they were completely satisfied with their logistics processes. The vast majority (99 enterprises) were partially satisfied with the daily material flow, while 19 enterprises were not satisfied at all. In addition to the satisfaction of the enterprises, it was also worth examining how optimal the respondents saw the operation of their logistics processes. (At this question, we asked about the main factors that play a role in the life of an enterprise, for example: market and financial situation, IT and specialist supply, competitive situation, financing, access to raw materials, and the operation of logistics processes.)

59 enterprises out of the 147 respondents indicated that their logistics processes and the operation thereof can be considered average, but this was accompanied by 41 responses in which the "worse than average" was marked, while 32 respondents described the situation as significantly bad. In addition to satisfaction with the logistics processes and the actual operation of the logistics processes, it was also worth examining the demand for software

support for possible problems. Within this question, 64.58% of the respondents answered that they would use a decision support software that supports logistics processes to reorganize the logistics processes of the enterprise, thus there was a real need for a new type of approach in this field. (Freedman – Pisani - Purves, 2005)

Based on the summary of the answers, I got the result that since 67% of the 147 enterprises were partially satisfied, while 13% were not satisfied at all, and 49.66% considered the operation of their logistics processes to be worse than average, and combined with this, 64.58% would require a new decision support software that would allow them to reorganize their logistics processes, therefore I accepted the hypothesis, which thus became a thesis.

**THESIS 2 – There are regular and significant delays (felt by the enterprises of Zala County) in the logistics processes of Zala County enterprises**

After assessing the basic market demand and satisfaction, it was logical to explore the root causes of logistics problems. The question arose as to how significant these problems were at all, and whether the current situation was worth re-planning. For this, I measured the size of the problems perceived by enterprises and the frequency of the delays in the first place.

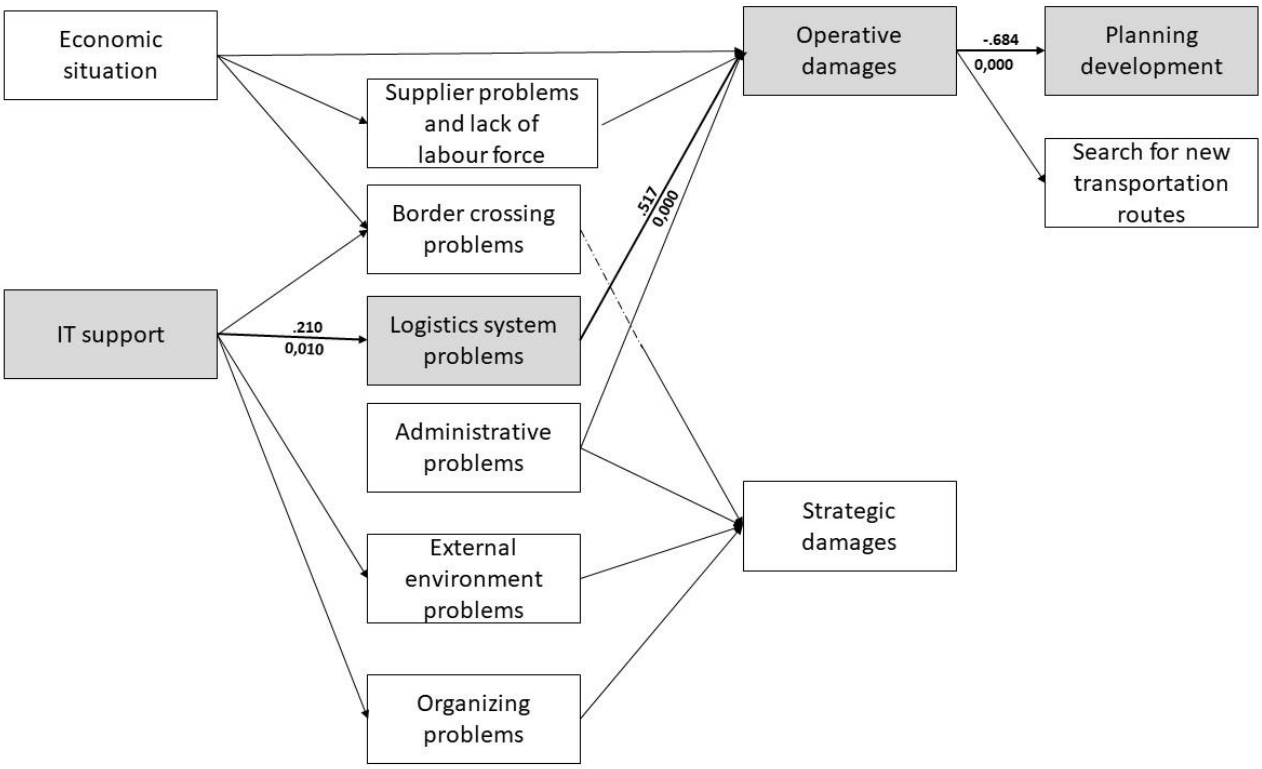
With regard to the latter, I asked how many deliveries out of 100 cases were delayed at the given enterprise. 46.26% of the respondents (68 enterprises) indicated 1-5 times, while, on average, 23-23% indicated 5-10 and 10-25 times, respectively. 4.76% of the respondents had regular delays 25-50 times, but there were also enterprises (2.04% - 3 enterprises) where there were some kind of problem 75-100 times (!), that is in almost all cases. It was interesting that no enterprises marked 0 occasions. Based on this, it can be stated that there was a regular blockage in the material flow level in case of Zala County enterprises, only its significance was in question.

In order to get to know the magnitude of the problem, I asked about the extent of these delays. Did they affect production or customer satisfaction, or were they completely negligible? 48.98% of the respondents answered that these delays were minor ones, while the remaining 51.02% said these affected production/customer satisfaction. In case of 14 of these enterprises (9.52%), the experienced delays had a significant influence. Based on the results obtained and in the light of these, namely that regular delays were experienced in almost all of the enterprises, typically 5-25 times per 100 cases, and in the majority of cases (51.02%) these delays had some influencing power, I also accepted the second hypothesis, thus this also became a thesis.

**THESIS 3 – The IT support of local enterprises and the efficiency of their capacities directly affects - at the system level - their logistics processes, in which low efficiency causes operational damage.**

After assessing the general satisfaction and root causes, I felt it was important to get to know the overall picture regarding logistics processes in the county, within which I tried to chart how the use of logistics IT by local enterprises affects system-level operations. In order to understand the question, I performed an SPSS analysis on the sample received, based on which I created the structural equation model (SEM model) of the logistics processes of Zala County enterprises to test hypothesis H3.

2. Figure: **Relevant relations in connection with H3 hypothesis**




[Source: own source] * n= 147

If we intend to understand the route, then we can say that, based on the route, the efficiency of the IT support and capacity of local enterprises directly influenced their logistics processes at the system level, during which the low efficiency caused operational damage in reality, as well. Based on the examination of the model, a large part of the hypothesis was confirmed, all that remains was to examine the development needs for solving the problems and the caused damages. (In'nami - Koizumi, 2013, pp. 23–51)

To do this, we had to examine the relations between operational damages and design development. Prior to the research, I expected a strong positive correlation between the two factors, but the results I got showed exactly the opposite. Basically, this means that most businesses answered that despite their high operational losses, they had minimal design development needs. Certainly, the opposite was also true, that is in the case of a small amount of existing damage, there was a high demand for design development.

This direction of the connection was surprising at first, but after re-checking the sample, there were already some possible explanations for the phenomenon. One such explanation could be that if the given enterprise prospers, suffers little damage, and has adequate economic conditions, it can spend much more on strategic and operational planning. Essentially, this can cause a paradox in the model, within which such companies pay special attention to planning, and they constantly look for new approaches to efficient operation, as a result of which their operational losses remain low. (In summary: high planning requirements, low damages.)

Certainly, this is also true the other way around, which means that for other types of companies, if they do not look for new development tools despite the serious operational damages. Based on the answers, it has been confirmed that the companies that suffer the most operational damage are those that are mostly unable to allocate sufficient resources to operational and strategic planning. The attitude of the enterprises to the given problems and damages reflected the state described earlier, namely since the IT support was not adequate, the logistics system problems and the operational damages were serious, therefore in this state the planning was essentially considered unnecessary by the company managers (unfortunately).

In comparison, another group of respondents would have tried to improve, namely they had the right attitude, but these enterprises typically did not have the necessary planning techniques, or simply did not know the role of planning in crisis management. Overall, the result was the same in both cases.

In summary, if we want to summarize the model and its connections, the local companies, based on the model, can be characterized by the following key factors:

- The majority of companies have a certain level of IT support and capacity in the supply chain, but the utilization of capacity is inefficient;
- Poor utilization of capacities causes serious logistical problems at the system level;
- Immediate and direct operational damages arise from these difficulties to the everyday flow of materials;
- Prosperous companies can manage these problems with proper planning (e.g. PDCA method) and keep the damages at a low level.
- In spite of all this, these enterprises show significant needs towards planning and new approach, based on the entire model;
- In the current situation, the majority of local enterprises are struggling with serious system problems that cause operational damage. This is partly due to the fact that they do not pay enough attention to planning and the introduction of new tools.

Based on the results obtained, we can conclude that the local enterprises use their IT capacities below optimum, the infrastructure and technology are not properly exploited in most cases. Improper use causes logistics system problems, which in turn leads to direct operational damage. On the basis of these, I have partially accepted the third hypothesis, which thus became a thesis.

**THESIS 4 - The logistics processes of enterprises can be modelled starting from internal processes, and the simulation carried out on the model may be suitable for the development of a future decision support system/application.**

The basic dimensions of the model to be built were determined with the help of qualitative sampling, which included the following variables: date/exact time, travel time, temperature, precipitation, wind, possible accident, other comments. To build the model, I tested the order times within the enterprise, that is I examined the individual dimensions (e.g. precipitation, temperature, etc.) for a given time, and also the related, expected travel time.
Accordingly, I started from the following measured variables during the development of the simulation model:

- $m \in \{1, \ldots, 12\}$ – date of the trip (month), discrete scale

- $t_0 \in \{0, \ldots, 24\}$ – time of departure (hours, minutes, in the model the minutes are given in fractional hours for simplification), continuous scale
- $t$ – travel time (minutes), continuous scale
- $\phi$ – weather conditions (precipitation, temperature, wind speed)
- $\psi$ – unusual circumstances (accident, road closure, major congestion), dummy

Using the measured data, I created the database necessary for the simulation, for which I used the Monte Carlo simulation technique. I explained, from the measured data, to what extent the factors influenced the travel time. The **average travel time** took 156.7 minutes, so I divided the sample into two parts at this average value, so that 54.5% of the cases had travel time below the average, while 45.5% had travel time above the average. I have created 5,000 simulated start times for the corresponding database. The simulated start time was a random variable with random parameters that scattered around two peaks, and could be described by a so-called bimodal distribution. The distribution function for such bimodal distributions had two peaks (local maximums). For the simulation of a single random delivery time, we started from the following parameters (for which we infered from the distribution of the measured data):

1. Table: **Simulation of departure times**

| | |
|---|---|
| Most likely departure time (morning; afternoon): $X$ random variable that follows a binomial distribution | $P(X=k) = \binom{n}{k} \times p_1^k \times p_2^k$ |
| Probability of departure in the morning $(i = 1)$ | $p_1 = 0{,}6$ |
| Probability of departure in the afternoon $(i = 2)$ | $p_2 = 0{,}4$ |
| The departure time within the day is a random variable with a normal distribution | $D \sim \mathcal{N}(E(t_0)_i; \sigma_i)$ |
| Expected value of departure time in the morning $(i = 1)$ | $E(t_0)_1 = 9$ |
| Expected value of departure time in the afternoon $(i = 2)$ | $E(t_0)_2 = 18$ |
| Morning departure time standard deviation $(i = 1)$ | $\sigma_1 = 2{,}5$ |
| Afternoon departure time standard deviation $(i = 2)$ | $\sigma_2 = 2{,}5$ |
| Probability of departure in the morning $(i = 1)$ | $P_1 = 0{,}6$ |
| Probability of departure in the afternoon $(i = 2)$ | $P_2 = 0{,}4$ |

[Source: own source]

3. Figure: **Implementation of simulated departure times in Excel**

**Simulation of a delivery**

| | Morning | Afternoon |
|---|---|---|
| Exp. value | 9 | 18 |
| Deviation | 2,5 | 2,5 |
| Probability | 0,6 | 0,4 |

| | Departure time |
|---|---|
| 1. | = CHOOSE( IF (RAN()<=$C$8;1;2);(NORM.INVERS (RAN();$C$6;$C$7));(NORM.INVERS (RAN();$D$6;$D$7))) |
| 2. | 9,637 |
| 3. | 10,483 |

[Source: own source]

In the next step, I simulated ad-hoc events as well. Based on the measurements, the probability of unusual events (accidents, road closures, major congestion) was high, this occurs with a 44.16% chance for all measurements during a trip, this probability was only 16.6% in the case of below-average travel times, however, in an above-average case, the chance was 77.1%. Taking the measured data into account, we could consider the unusual events to be random variables with a binomial distribution, the probability of occurrence of which was 44.2%:

$$\psi \sim \mathcal{B}(n;p)$$

And the $\alpha$ limit value was random, the number of Bernoulli trials: n=1. In the third step, the weather was simulated: We knew from the measurements that in two-thirds of the cases (57.5%) there was no precipitation at all, or it was a negligible amount of rain (≤ 5mm). However, when it rained, it was 29 mm on average, but even this level of precipitation did not significantly increase the travel time (3-4 minutes, on average). However, the average travel time increased significantly by 20 minutes above 30 mm of rainfall. We conclude from these characteristics that the distribution of precipitation was asymmetric, following a $\beta$-distribution. Since the analysis of the measured data showed that the travel time was independent of the temperature and wind speed, these were not included in the simulation model. The sample $\beta$-distribution was also mapped in the simulation database, with the following parameters:

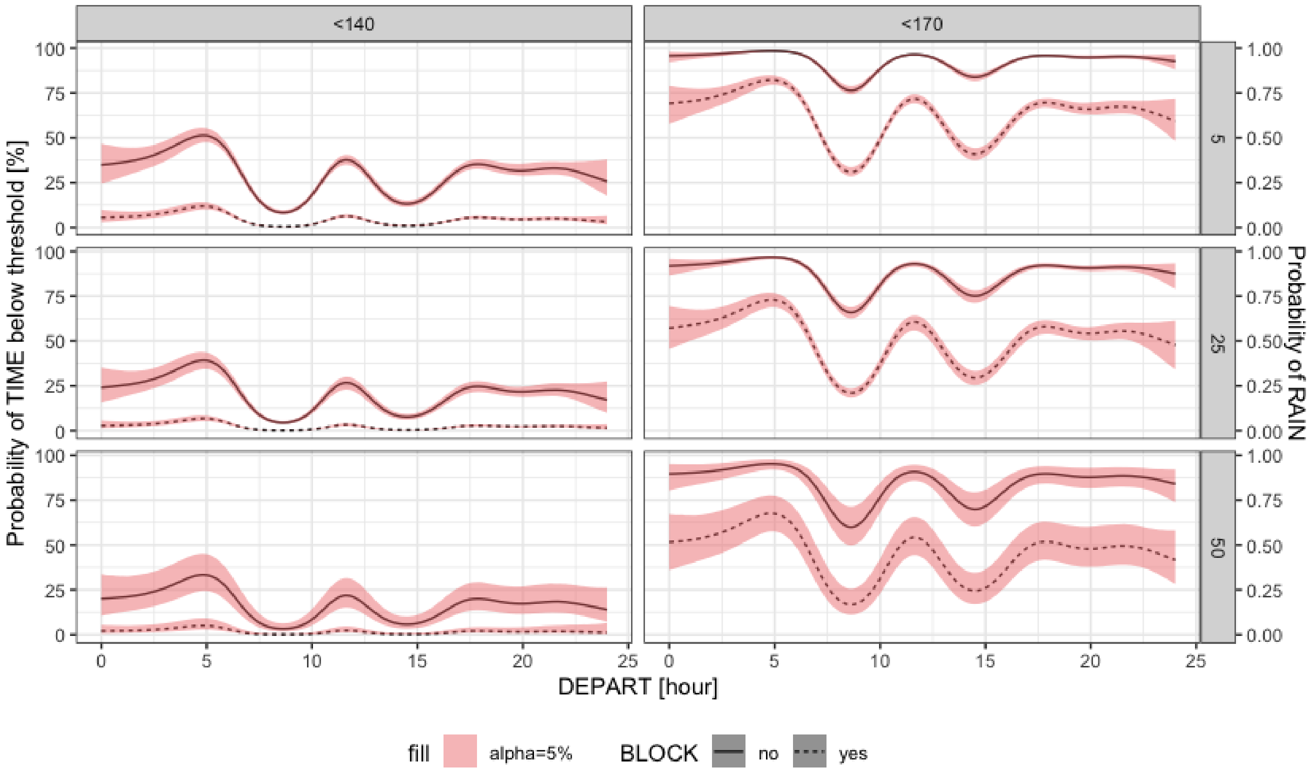
$$x = \text{random}$$

$$\alpha = 2;\ \beta = 10; A = -10; B = 100$$

These parameters were formed on the basis of observations, thus the $\beta$-distribution, which can be observed also in reality, can be represented.

In the final step, I summarized the results obtained from the simulation model using the Bayesian approach. Here, I investigated how, in the case of certain events (departure time, precipitation, extraordinary event), the probability that the travel time did not exceed the 140-minute threshold, or the theoretical threshold of 170 minutes, developed. It could be clearly seen that the road closure reduced this probability by a third or a half, and that departing during times of peak traffic also significantly reduced the probability of a short travel time.

4. Figure: **Simulation of the delivery time with margin of error**




[Source: own source] * n= 5 000

One of the most important central questions during the research was how we could build a model the simulation of which could show which periods were recommended and which should have been avoided in terms of purchase and road transport. And in the second half of the hypothesis, I formulated whether the simulation solution that could be suitable for the development of a future decision support system/application could be determined with the help of mathematical tools. In view of the fact that we created the model suitable for this purpose, and with the help of the simulation we obtained the expected result, that is a prediction for the driving time of the given day under given conditions, therefore I accepted the fourth hypothesis, as well, which thus became a thesis.

## Practical results

I consider the practical findings of my research work as results, which provide help in the design of a simulation model that can be used to effectively reorganize logistics processes related to businesses. I formulated these below as findings.

**Finding 1** - The results confirmed that local businesses are mostly dissatisfied with their current logistics processes and have serious needs for new solutions in the field of logistics, so a new decision support software has a right to exist, and the Zala County enterprises do not shy away from redesigning their logistics processes.

**Finding 2** – The previously confirmed dissatisfaction is not a general, undefinable phenomenon, but actually has serious causes, as regular and significant delays are experienced in the logistics processes of local businesses. In essence, we gained an insight that continuous interruptions do not only cause "annoyance" or minimal extra work, but have a serious and regular impact on competition, so dissatisfaction is not limited to comfort aspects either, but company managers actually demand to eliminate errors, with which they try to improve their competitive position. Accordingly, the examination of the root causes was also important from the point of view of the learning of the significance of the delays. In light of the results, we learnt of a significance and volume that further justified the need for possible redesign.

**Finding 3** – Local businesses use their IT capacities below optimum, infrastructure and technology are not properly exploited in most cases. Improper use causes logistics system problems, which leads to direct operational damage.

**Finding 4** - Local businesses with adequate economic capabilities spend much more on strategic and operational planning. This essentially results that these companies (with a strong background capital) pay special attention to planning and constantly looking for new approaches to efficient operation and as a result of which their operating losses remain low.

**Finding 5** – Another group of respondents is not looking for new development tools despite serious operational damage. Based on the answers, it was confirmed the companies that suffer the most operational damage are those that are mostly unable to devote sufficient resources to operational and strategic planning. The attitude of the enterprises to the given problems and damages reflected the state described earlier, i.e. since the IT support is not adequate, the logistics system problems and operational damages are serious, as a result of which in this state, the company managers consider the planning to be essentially unnecessary.

**Finding 6** – The logistics processes of enterprises can be modeled starting from internal processes, and the simulation performed on the model can be suitable for the development of a future decision support system/application. The research properly mapped a specific segment of this complex problem and presented the basic principles of a possible solution.

## Summary of the new and novel scientific results

In the framework of the research, the logistics processes of Zala County enterprises was successfully analysed, within which the satisfaction with the processes, the main sources of problems, the significance and effects of interruptions and delays were presented. In terms of satisfaction with the processes, it can be said that a large majority of local businesses showed dissatisfaction with their current logistics processes. Nearly two-thirds of the respondents would use the possible decision support software, so in summary it can be stated that there is an actual measurable demand for the reorganization.

Examining the frequency and importance of interruptions, we came to the conclusion that almost all of the respondents have some kind of delay, half of which essentially have a strong influence. In connection with this, it can be stated that the previously measured dissatisfaction is essentially justified during a deeper examination of the processes. It is not only a matter of general dissatisfaction and a need for development, but behind the result there are clearly visible disruptions.

With the help of the SEM model, a comprehensive picture of the situation was presented, where we mapped the cause-and-effect effects in more depth. Regarding the results, it was visible that local businesses do not exploit their IT capacities, they use them below optimum. The resulting inadequate logistics operation causes system problems, which in turn leads to direct operational damage. On the other hand, the needs for bridging the problem are present oppositely, i.e. the companies that use the IT infrastructure efficiently show a need for development, and those companies that do not use it properly do not show a need for this kind of development. This is partly due to the fact that prosperous companies operate their logistics systems properly due to the constant search for improvement, while companies in a worse situation either do not deal with new solutions or simply do not have the resources to implement them.

In the final segment of the research, simulation was used to create a solution that could form the basis of a future decision support tool. During the simulation, it was proven that the logistics processes of enterprises can be modeled starting from internal processes, and the simulation performed on the model can be suitable for the development of a future decision support system/application. It is important to emphasize that we have solved a well-delineated part of this very complex problem, which still requires a lot of further research.

# CONCLUSIONS AND PROPOSALS

Based on the results, I consider the simulation of the logistics processes of enterprises based on data within the enterprise to be worthy of further investigation. As mentioned earlier, the present research and its results should be treated as having examined a specific "slice" of this multifactorial problem and found a possible solution to it. If we look at the additional tasks of decision support software development, the following should be considered:

- Deeper testing of current simulation – with the help of stopwatch and other measurements tools.
- Examination of other geographical areas - this research was limited to Zala County only.
- Examining the issue of border crossing - with similar tools as in the present research.
- Further research according to other ways of transport and combined transport - in the thesis we examined road transport, including car and van transport. Rail, air, and water transport are currently not in focus, and the current results will have to be examined later for trucks and other tools as well.
- Unit load training and back office operations – The thesis considered unit load training and other back office operations to be constant; further the question is

whether the companies can meet this in case of a redesign of their logistics processes? (E.g. if we define a time limit for them in the case of recommending the order period, during which the training and loading of the unit load must be completed)

- Possible connection to AI (Artificial Intelligence) – although there are signs that there will be synergies between the development of AI and logistics simulation, the question is when the technology will reach the point where it can fully adapt the development. Currently, chatbots, personal assistants and maintenance planning tools are mostly being developed within company management software.
- Once these areas have been explored, the final task will be to design software solutions. On a theoretical level, the present research also dealt with the possibility, but this actual research output would represent a completely new topic due to its scope.

If we examine the shortcomings of the current research for the complete solution, we can clearly state that the final development is strongly tied to resources. In addition to time, the final product requires further examinations in other areas (with the help of external researchers, in a kind of "open source" manner) and company resources. Regardless of this, if we want to summarize the results of this research, we can once again say that an essential, central element of the entire development has been solved and we will continue the work started by examining additional dimensions and areas.

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1. *Szabó K. - Logisztikai folyamatok szimulációja Zala Megyei vállalkozásoknál* Logisztika-Informatika-Menedzsment Nemzetközi Konferencia, Zalaegerszeg (2019.12.05.)
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