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PREFACE

We started the *Advanced Logistic Systems* journal in 2007, to present the research results of the Institute of Logistics of the University of Miskolc and its partner institutes. As the Institute of Logistics works mainly in the field of material handling and logistics, so the main topic of the journal is related to logistic systems. However, during the last 60 years, the Institute (and its predecessors) dealt with not only this topic, but also achieved results in other fields of the industry, so time-to-time, we have to give place for researches related to other topics in the journal, at least some single paper pro year.

Importance of a research institute is depend on not only the research results, but also the reputation of the persons who work in its projects and play important role in the everyday life of the institute. Actual issue of the *Advanced Logistic Systems* journal gives place a paper prepared by prof. emeritus dr. Sándor Szaladnya in his 92nd year, and present an example from his arborescent research activities.

Prof. emeritus dr. Sándor Szaladnya is one of those persons who had significant role in the Institute of Logistics during the last 6 decades. Beside his research results, his attitude and professional calling had great influence on generations of researchers and teachers of the Institute. He retired in 1991, but he takes part in the education and research activities of the University of Miskolc until these days. His professional and public activities and positions in different social and scientific associations are recognized with many awards and medals. For us, he is a timeless – in mind and body –, fit and kind friend and colleague.

In this issue, we publish his paper on the Foucault-pendulum, which has no direct relation to the logistic systems, but the movement of the pendulum has important role in many part of the material handling (e. g. load lifting and transportation by cranes).

Of course, the main objective of this issue is to present new researches and results related to the logistic fields, to contribute to the development of the logistics sciences.

Dr. Péter Telek
associated professor
Chief Editor

Prof. dr. Béla Illés
university professor
Head of the Editorial Board

Miskolc, 15th December 2017

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PROF. EMER. DR. SÁNDOR SZALADNYA'S PROFESSIONAL PROFILE

Sándor Szaladnya was born in 22nd of 1926 in Kosice. After his education in the secondary school, he went to the Faculty of Mechanical Engineering of the University of Heavy Industry in Miskolc (predecessor of the University of Miskolc), where he was graduated in 1953. He started his carrier at the University as an aspirant between 1953 and 1956 than, as an assistant professor, between 1956 and 1962 and as an associated professor between 1962 and 1973 at the Department of Machine Elements. During these years he had also part jobs at the Institute of Machine Tool Development and the DIGÉP, where he was designer. In 1964 he obtained the Candidate of Engineering Sciences degree and doctorate in engineering (dr. tech.) from the Hungarian Academy of Sciences.

In 1973, he was nominated to university professor and for the head of the Silicate Engineering Division of the University of Heavy Industry in Miskolc. This new field was a part of the Department of Transport Machines (predecessor of the Institute of Logistics), and dealt with the machines and technologies of the Silicate Industry. He successfully managed the education and research activities of this area, built new relations with the experts and companies of the Silicate Industry and developed new curricula and courses to satisfy the requirements. Under his direction, the staff of the Division took part in many industrial and research projects, conferences and study trips. He had always good relations with the students, the class graduated in 1972 selected him as a honourable class-fellow and gave him the golden Ring of Engineering. Students of the Division won more times the study competition of the Faculty of Mechanical Engineering. He retired in 1991 and was nominated as Professor Emeritus of the University of Miskolc.

He has many functions during his career:

- Head of the Industrial Committee of the Faculty of Mechanical Engineering from 1956
- Member and Chief of the Scientific Society for Mechanical Engineering from 1958
- Member of the Council of the University of Heavy Industry in Miskolc between 1970 and 1976
- Vice-dean of the Faculty of Mechanical Engineering between 1970 and 1973
- Head of the Local organization in Borsod-Abaúj-Zemplén County of the Association of the Hungarian Scientific Societies between 1965 1990
- Member of the Country-wide Presidium of the Association of the Hungarian Scientific Societies from 1967
- Chief editor of the “Engineering and Industrial-economic Life in Borsod” journal form 1977
- Member of the Country-wide Committee of the Scientific Society of the Silicate Industry from 1977

- Member of the Professional Committee in Mechanical Engineering of the Regional Committee of the Hungarian Academy of Sciences in Miskolc form 1980
- Member of the Scientific Council of the Central Institute for Research and Design of the Silicate Industry from 1985

His professional activities were recognized by not only the students, but his colleagues and partners, because he built close relations with many experts of the Glass-, Ceramic-, Cement-, Concrete- and Insulating material-industry. He successfully managed Professional trainings for Engineers of the Glass- and Ceramic-Industry, where near 50 experts graduated.

He had accentuated role at the building of the House of Engineering in Miskolc, as the secretary of the Local organization of the Association of the Hungarian Scientific Societies, he managed the activities and enforced the relations among Miskolc and the University establishing the yearly event "Engineering Weeks in Borsod".

He was one of the founding fathers and the first Head of the Bánkút Ski Club in 1972, which was the basis of the development of the ski-sport in North Hungary.

In recognition of his wide-range activities, he has got many awards:

- Excellent worker of the Machine Industry (1965)
- Class I. Award of the Association of the Hungarian Scientific Societies (1970)
- Excellent worker of the ÉVM (1970)
- Award of the Local organization in Borsod-Abaúj-Zemplén County of the Association of the Hungarian Scientific Societies (1983)
- Order of Labour, Golden class (1986)
- Medal of the Faculty of Mechanical Engineering (1991)

Prof. Sándor Szaladnya's education activities are very colourful. At the Department of Machine Elements he taught the courses "Practical mechanic" and "Hydraulics and pneumatics", at the Department of Transport Machines he taught the courses "Factory planning", "Machines of the silicate industry" and "Machines of the Glass- and Ceramic-industry". Into the last two courses, he involved the devices of the automated operation, as the pneumatic, hydraulic, PLC and computer control.

His research activities were related to industrial problems, especially the automation of the machines. Related to this topic, he had many development ideas, which were introduced in the practice, e. g. the invention "Pneumatic device for automatic strand-stretching control" (with co-author), which was accepted in several countries (Hungary, Russia, Germany, Poland, Great Britain). He initiated the standing of a Foucault-pendulum at the University of Miskolc and calculated the parameters of the installed pendulum (with co-author). He achieved considerable results on the theoretical and experimental analysis of remained stresses in glasses because of the cooling process. He developed measuring methods to determine the extrusion parameters of the semi-dry pressing and applied them in the dimensioning process of different press machines.

He established important relations to the Technical University of Kosice, the Freiberg University of Mining, the Technical University of Berlin, the Bauman University of Moscow, etc. During his 60 years, he presented his results in many national and international conferences and journals.

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THE FOUCAULT-PENDULUM

SÁNDOR SZALADNYA[1]

Abstract: In the material handling, there are many machines in which the goods can swing during transport or loading. The greatest impact of this phenomenon is appearing during the operation of different cranes, where the goods are moving as a pendulum. In 1851, Jean Foucault presented a strand-pendulum, which was used to demonstrate the rotation of the Earth. This Foucault-pendulum and its describing equations can help to understand the behaviour of the swinging bodies and the rules which influence their movement. In this paper, the author presents the importance and the essential formulas to describe the behaviour of a pendulum, using the data of the Foucault-pendulum built at the main entrance of the University of Miskolc as a reference object.

Keywords: *swinging, absorption, Coriolis-force, load-swinging*

1. INTRODUCTION

In 1851, Jean Foucault presented a strand-pendulum, which was used to demonstrate the rotation of the Earth. This Foucault-pendulum and its describing equations can help to understand the behaviour of the swinging bodies and the rules which influence their movement. In the material handling, there are many machines in which the goods can swing during transport or loading. The greatest impact of this phenomenon is appearing during the operation of different cranes, where the goods at the end of the lifting cable are moving as a pendulum. A Foucault-pendulum built in 2000 at the main entrance of the University of Miskolc [1], which is a suitable reference object to apply and analyse the pendulum-movement.

2. JEAN FOUCAULT

Jean Foucault was born on 18 September 1819 in Paris, in a rich family. In his 10th year, he started his studies in the “Colleg Stanislas” in Paris, but because of his non suitable diligence, he was taught away form the school. After it, he finished his studies at private teacher. He also abandoned his medical study at the University of Paris due to a blood phobia.

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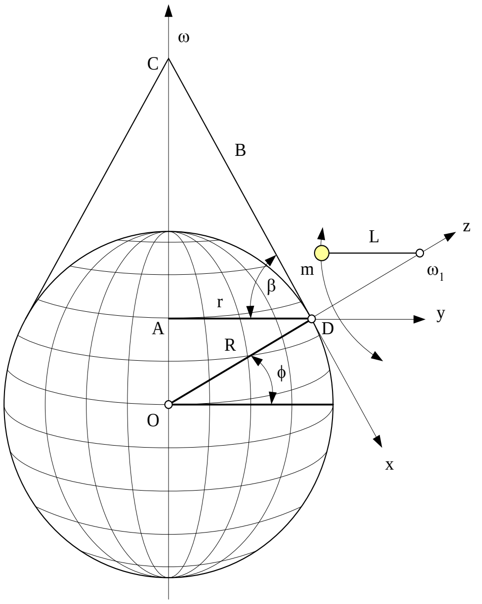
Foucault started to work in 1844, in his 25th year, he was scientific reporter at a journal and dealt with the refraction and the determination of the transmission speed of the light. He and Armand Fizeau developed an apparatus with gears and rotating mirror to measure the speed of the light. The gyroscope is also Jean Foucault's invention.

In 1851, Foucault presented a 68 meters long strand-pendulum to the wide audience, which could be used to demonstrate the rotation of the Earth spectacularly. This pendulum as Foucault-pendulum was entered into the History.

3. UNDAMPED PENDULUM MOVEMENT

To describe the movement of a mathematical pendulum, we have to analyse the movement of a weightless and inflexible material point effected by the gravity force. In this analysis we are dealing with only the flat pendulum and aside from the effects of the Earth's rotation [3]. Movement, location and data of the Foucault-pendulum built at the University of Miskolc can be seen in *Figure 1* and *2*.



Data:

- $R = 6.378\cdot10^6$ m
- $\phi^M = 48.1^o$
- $r = R\cdot\cos\phi^M = 4259.4$ km
- calendar day:
  $T_n = 24\cdot3600 = 86400$ s
- angular speed of the Earth:
  $\omega_F = 7.268\cdot10^{-5}$ 1/s

$$\omega_F = \frac{2\times\pi}{T_n} = \frac{2\times3.14}{24\times3600} = 7.268\times10^{-5}\,\frac{1}{s}$$

- gravity acceleration:
  $g = 9.832 - 0.052\cdot\cos\phi^M =$
  $= 9.81$ m/s^2

Figure 1. Geometric data of the Foucault-pendulum [3]

Basic equations to describe the movement of the pendulum:

- moment of the inertia force calculated to the axis of rotation:

$$M_t = m\cdot L^2\cdot\frac{d^2}{dt^2}\alpha \tag{1}$$

- moment of the weight force calculated to the axis of rotation:

$$M_g = -L\cdot m\cdot g\cdot\sin\alpha \tag{2}$$

For small angles $sin\alpha = \alpha$, so

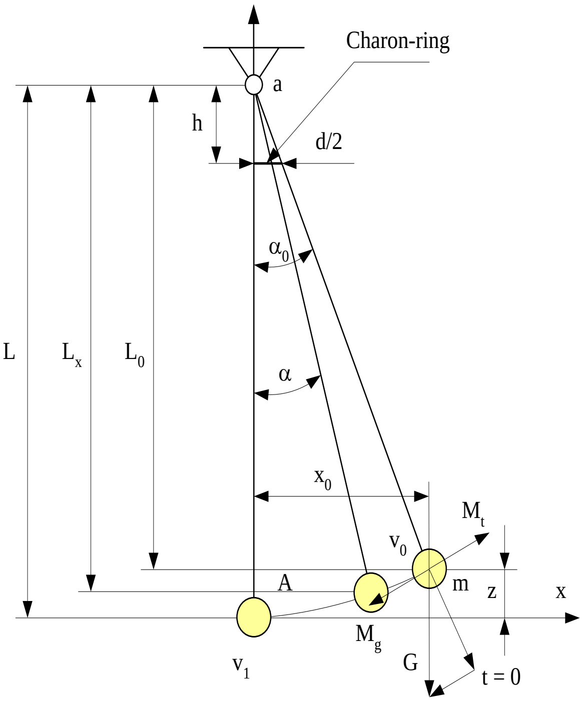
$$M_t = M_g \tag{3}$$

$$\frac{d^2\alpha}{dt^2} + \frac{g}{L} \cdot \alpha \cong 0 \tag{4}$$

$$\frac{g}{L} = \omega^2, \omega = \omega_0 \tag{5}$$

$$\frac{d^2\alpha}{dt^2} = -\omega^2 \cdot \alpha \tag{6}$$

Equation (6) is the differential equation of the undamped harmonic oscillation.



Data of the pendulum at Miskolc:

- α = 3–7°
- length of the strand:
  L = 10.4 m
- swinging mass:
  m = 42 kg

Figure 2. Forces effect the pendulum [2]

Dumped harmonic oscillation can be done by a body, if the size of the acceleration is proportional to the movement, but its direction is opposite. This kind of oscillation is valid for the mathematical pendulum. In our analysis we use Cartesian coordinate system.

As it can be seen in *Figure 2* and *3* (Figures are not scaled) L = 10.4m, N = h = 0.16m, d = 0.016 m – diameter of the Charon-ring (see *Figure 2*), which localizes the motion of the pendulum. If the amplitude of the swinging is small, when $x_0/L = 0.052$ and $Z/L = 0.0014$ values are small, the end point of the pendulum is approximately follow angle x (see *Figure 3*).

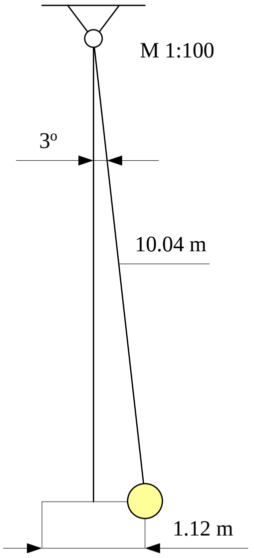


Figure 3. Effect of the Charon-ring

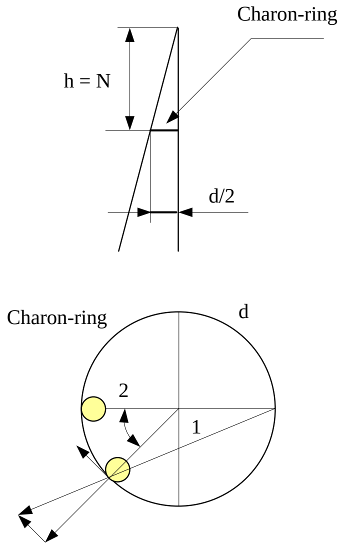


Figure 4. Geometry of the Charon-ring

Using the described values and $\alpha_0 = 3^o$:

$$tg\alpha = \frac{d/2}{N} = 0.05 \quad I_v = L \cdot \frac{3 \cdot \pi}{180} = 0.5445m$$

$$x_0 = L \cdot \sin\alpha_0 = 0.544m \quad L_0 = L \cdot \cos\alpha = 10.385m$$

$$Z = L - L_0 = 0.015m \quad v_1 = \sqrt{2 \cdot g \cdot Z} = 0.542m/s$$

Movement function of the pendulum in direction x – horizontal movement above the table- in time can be described by the next equation with acceptable approximation:

$$\ddot{x} = -\omega^2 \cdot x \tag{7}$$

Equation (7) is a linear differential equation of the second order with constant coefficients, which is suitable to analyse the undamped pendulum movement. Its characteristic equation is $\lambda^2 + \omega^2 = 0$, its roots are $\lambda_{1,2} = \pm\, \omega i$. General solution of the differential equation is

$$x(t) = c_1 \cdot \cos\omega \cdot t + c_2 \cdot \sin\omega \cdot t \tag{8}$$

If we apply equation (8) for the pendulum taking *Figure 2* into consideration and determine the values of c_1, c_2 constants:

$$\frac{d}{dt}x(t) = v(t) = -c_1 \cdot \sin(\omega \cdot t) \cdot \omega + c_2 \cdot \cos(\omega \cdot t) \cdot \omega \tag{9}$$

If t = 0, x(0) = 0.544, v_0 = 0, c_2 = 0, then $\omega = \sqrt{\frac{g}{L}} = 0.971$.

Taking the above mentioned into account:

$$x(t) = c_1 \cdot \cos(\omega \cdot t) \tag{10}$$

$$v(t) = c_1 \cdot \omega \cdot \sin(\omega \cdot t) \tag{11}$$

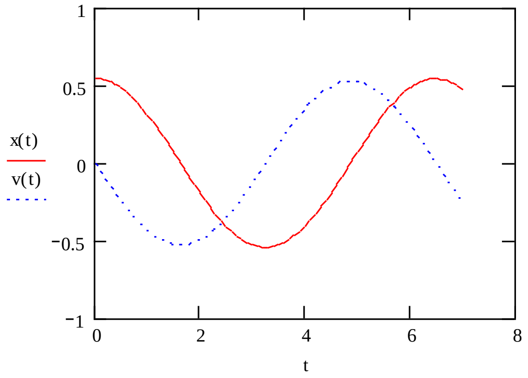


Figure 5. Movement and velocity of the pendulum in time

4. DAMPED PENDULUM MOVEMENT

If the energy of the movement of the pendulum is absorbed by anything (e. g. friction), then we talk about damped pendulum movement. In this case the pendulum movement is proportional to the acceleration and the velocity, but its direction is opposite to both of them.

4.1. Equations for damped pendulum movement

Differential equation to describe the movement:

$$m \cdot \frac{d^2x}{dt^2} = -\omega^2 \cdot m \cdot x - 2 \cdot s \cdot \frac{dx}{dt} \tag{12}$$

where

- *m* – mass of the moving body [kg],
- *s* – dumping coefficient.

If we divide equation (12) by *m* and use the *s/m* = *k* marking, as a resistance factor, then

$$\frac{d^2x}{dt^2} + 2 \cdot k \cdot \frac{dx}{dt} + \omega^2 \cdot x = 0 \tag{13}$$

where $\omega \geq 0$ is a constant and *k* is a positive constant value.

The characteristic equation of the homogeneous differential equation of the second order with constant coefficients is

$$\lambda^2 + 2 \cdot k \cdot \lambda + \omega^2 = 0 \tag{14}$$

and its roots are

$$\lambda_{1,2} = -k \pm \sqrt{k^2 - \omega^2} \tag{15}$$

If $k < \omega$, i. e. $\sqrt{k^2 - \omega^2} < 0$, then the roots of the characteristic equation are complex values, so

$$\lambda_{1,2} = -k \pm i \cdot \sqrt{k^2 - \omega^2} < 0 \tag{16}$$

This case will be used for the following analysis of the pendulum.

In case of dumped movement, two other equations are required to determine the values of c_1, c_2 constants in the general solution:

$$x(t) = e^{-k \cdot t} \cdot \left[c_1 \cdot \cos\left(\sqrt{\omega^2 - k^2} \cdot t\right) + c_2 \cdot \sin\left(\sqrt{\omega^2 - k^2} \cdot t\right) \right] \tag{17}$$

$$\begin{aligned} \frac{d}{dt} x(t) = & -k \cdot e^{-k \cdot t} \cdot \left[c_1 \cdot \cos\left(\sqrt{\omega^2 - k^2} \cdot t\right) + c_2 \cdot \sin\left(\sqrt{\omega^2 - k^2} \cdot t\right) \right] + \\ & + e^{-k \cdot t} \cdot \left[-c_1 \cdot \sin\left(\sqrt{\omega^2 - k^2} \cdot t\right) \cdot \sqrt{\omega^2 - k^2} + c_2 \cdot \cos\left(\sqrt{\omega^2 - k^2} \cdot t\right) \cdot \sqrt{\omega^2 - k^2} \right] \end{aligned} \tag{18}$$

It can be read from equation (17) and (18), that the pendulum movement is a periodic function in time, its amplitude is decreasing exponentially with the increasing of the *t* value, which results the damping effect. If we release the pendulum in state “0”, its movement will be as it can be seen in *Figure 6* and *7*. In case of small amplitude, x(290·T) = 0,1 mm, the kinetic energy of the pendulum is so low, that the movement of the surrounding air can also affect the pendulum movement (v = 0.048 m/s). The value of the “k” factor used in the equations is calculated on previous observations, which will be corrected based on practical measures.

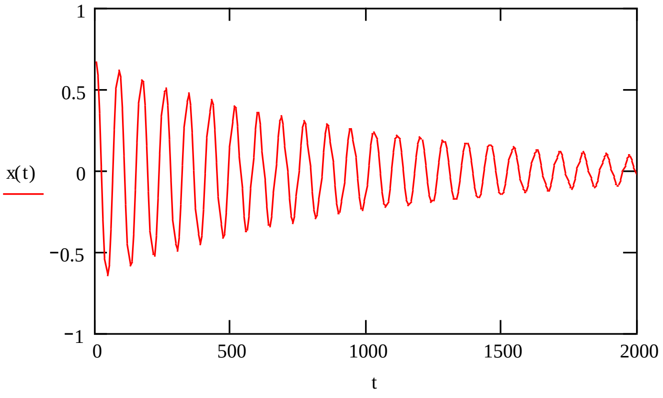


Figure 6. Pendulum movement

In the knowledge of the values of the constants, the damped pendulum movement and velocity can be depicted in time *(Figure 6* and *7).*

The values of the constants are $k = 0.001$, $\omega = 0.971$ 1/s, $c_1 = 0.669$, $c_2 = \frac{-k \cdot c_1}{\sqrt{\omega^2 - k^2}}$.

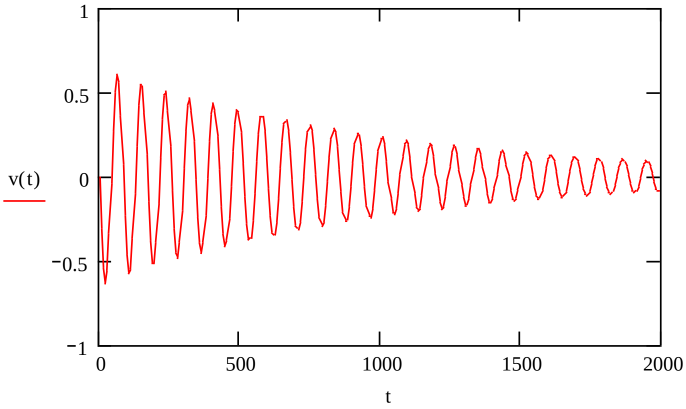


Figure 7. Velocity of the pendulum

As the results of the above described process are not sufficient to the further analysis of the pendulum movement, so we have to introduce new equations.

4.2. Determination of the period of the pendulum movement

The period of the movement of the Foucault-pendulum built in Miskolc, based on the equations in the related literatures [5]:

$$T = 4 \cdot \sqrt{\frac{L}{g}} \cdot \int_0^{\frac{\pi}{2}} \frac{1}{\sqrt{1 - x^2 \cdot \sin(\alpha)^2}} d\alpha \qquad (19)$$

Applying the data of the pendulum ($\alpha = 3^o$-4^o, L = 10.4 m, g = 9.81 m/s^2, $\omega = 0.971$ 1/s) and $x = \sin(\alpha_0/2)$ the calculated period of the pendulum movement is T = 6.47 s.

Determination of the period is even simpler, if $\alpha < 8^o$:

$$T = 2 \cdot \pi \cdot \sqrt{\frac{L}{g}} \qquad (20)$$

In this case, the calculated period of the movement is T = 6.469 s.

We can establish that the period of the pendulum movement is not depending on the mass and the amplitude of the pendulum. It means that the same pendulums in length with different masses and amplitudes (small) on the same location of the Earth have the same movement period. This is the rule of isochronous time which was discovered by Galilei, which will be taken into account in the analysis of the damped pendulum movement, for the evaluation of the measuring results. Confirm this rule using equation (17) with suitable transformations and variable amplitudes:

$$x(t,c_1)=e^{-k\cdot t}\cdot\left[c_1\cdot\cos\left(\sqrt{\omega^2-k^2}\cdot t\right)+\frac{-k\cdot c_1}{\sqrt{\omega^2-k^2}}\cdot\sin\left(\sqrt{\omega^2-k^2}\cdot t\right)\right] \qquad (21)$$

We can see in Figure 8, that the movement period is the same for all amplitude variations.

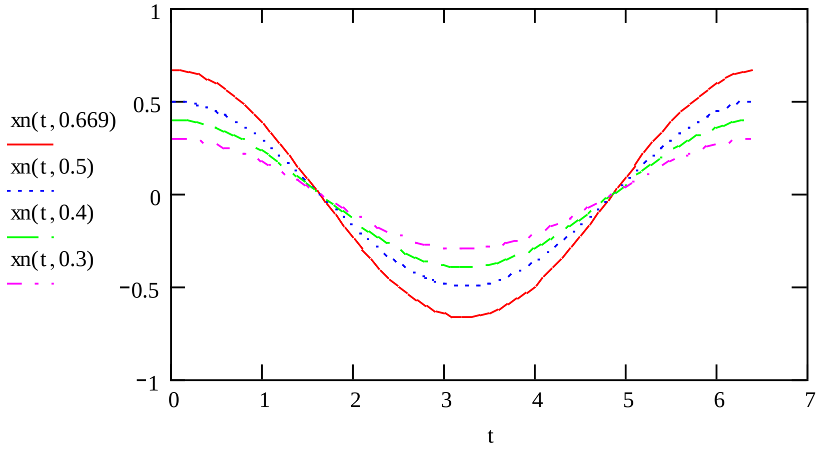


Figure 8. Effect of the amplitude changing to the period of the movement
k = 0.001, ω = 0.971 1/s, T = 6.47 s

4.3. Comparison of the calculated and measured values of the period of the pendulum movement, determination of the resistant factor

Curves resulted by the equations described before show that after releasing, the kinetic energy of the pendulum is decreasing. To keep the pendulum in continuous moving, it is required to refill the energy, so on certain places, magnetic push have to be used.

As our objective is to determine the value of the “k” resistant factor, so we realized our measuring after switching the magnet off. During the motion we measured the decreasing values of the amplitude of the pendulum. Starting value of the amplitude $x_0 = 0.669$ m was at t = 0 s.

Applying the results of the measures *(Table I)* and equations (17) and (18) we determined the real value of the *t* factor. Solving equation (17) with the new values we got *Figure 9*, where k = 0.002, ω = 0.971 1/s, $c_1 = 0.669$.

As it was described before, the decreasing of the amplitude does not influence the period of the movement *(Figure 8)*, so calculating the movement on integer multiples of the period x(n·T) results an envelope for the decreasing of the amplitude *(Figure 10)*.

Calculated values of the movement are based on equation (17) and involved in *Table II*. Curve x(n, T) is the upper envelope of the x(t) function. This curve will be compared to the envelope based on the measured (x_1) values *(Figure 11)*.

Last data of the measuring was $t_1 = 3600$ s (556.4·T), because at this point the kinetic energy of the pendulum was so low that the movement of the surrounding air effected it and the pendulum movement was transformed into spherical pendulum movement.

Table I.
Measuring results

Measure	x_1 [m]	t_1 [s]
1.	0.669	0
2.	0.64	120
3.	0.625	300
4.	0.61	360
5.	0.6	480
6.	0.588	540
7.	0.575	660
8.	0.563	780
9.	0.544	900
10.	0.525	1020
11.	0.506	1200
12.	0.485	1440
13.	0.461	1680
14.	0.438	1920
15.	0.414	2160
16.	0.398	2400
17.	0.376	2640
18.	0.357	2940
19.	0.341	3180
20.		3600

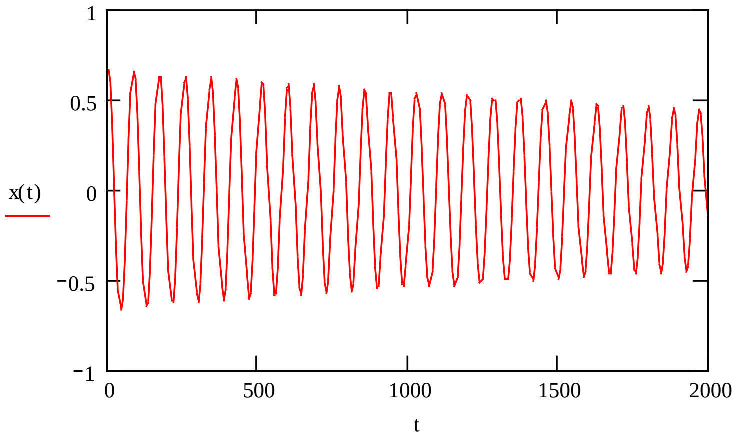


Figure 9. Decreasing of the amplitude of the movement with the corrected k value
$x(0) = 0.669$ m, $x(T) = 0.668$ m, $x(2 \cdot T) = 0.667$ m, $x(500 \cdot T) = 0.322$ m

Results based on equation (17) have suitable similarity to the measured values (Figure 11), so the value of the resistant factor can be recalculated

$$k = \frac{s}{m}, \quad k = 0.0002$$

Table II.
Calculated values of the upper envelope

	x [m]	**t [s]**
1.	0.669	0
2.	0.627	323.5
3.	0.586	647
4.	0.547	970.5
5.	0.510	1294
6.	0.474	1618
7.	0.440	1941
8.	0.408	2265
9.	0.378	2588
10.	0.349	2912
11.	0.322	3235
12.	0.296	3559
13.	0.272	3882
14.	0.249	4206
15.	0.228	4529

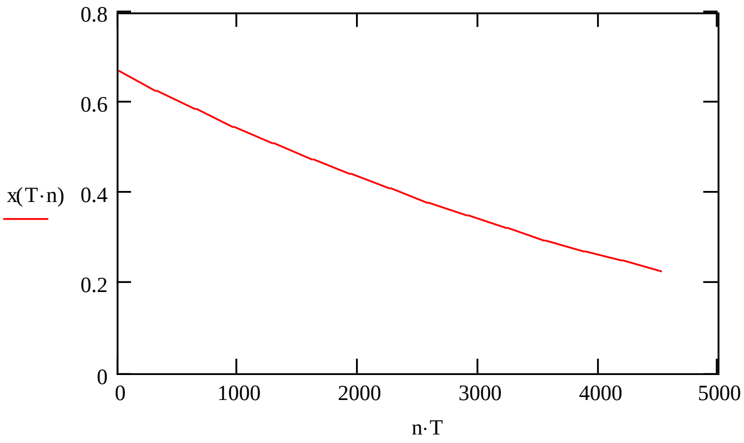


Figure 10. Upper envelope of the calculated amplitude values

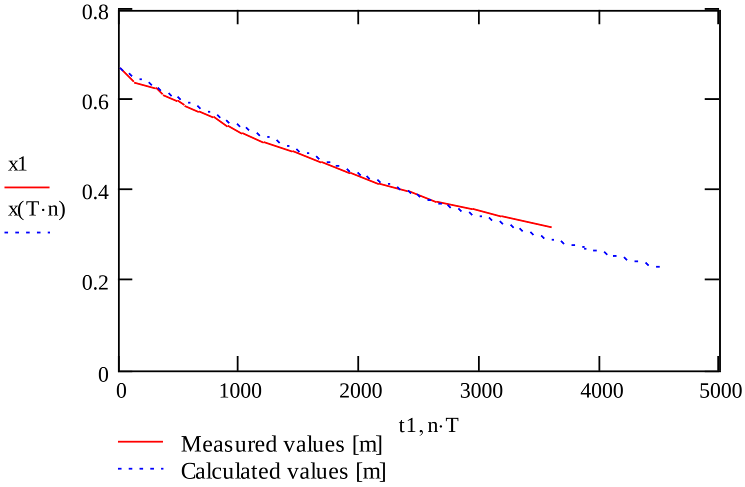


Figure 11. Comparison of the measured and calculated values

5. PENDULUM MOVEMENT ABOVE THE TABLE

5.1. Influencing forces

Figure 12 and *13* show the table and the above swinging pendulum located at the north side of the Earth [3]. The moving body (pendulum), related to the table, is influenced by not only the radial force but also another force which is an inertial force called Coriolis–force. In a rotating reference frame (see *Figure 14*), a force, perpendicular to the velocity, effects to the pendulum starting from point (1), which deflects it into point (2). This is the Coriolis-force.

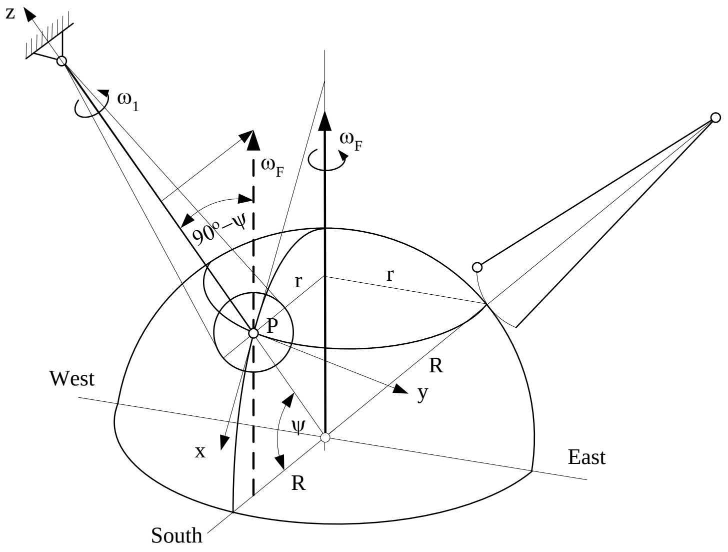


Figure 12. Forces effect the pendulum

In return phase, the same force influences the movement from point (2) to (3). The observer see that the plane of the pendulum movement does not change, but the table is moving. The movement of the table is proportional to the rotation of the Earth.

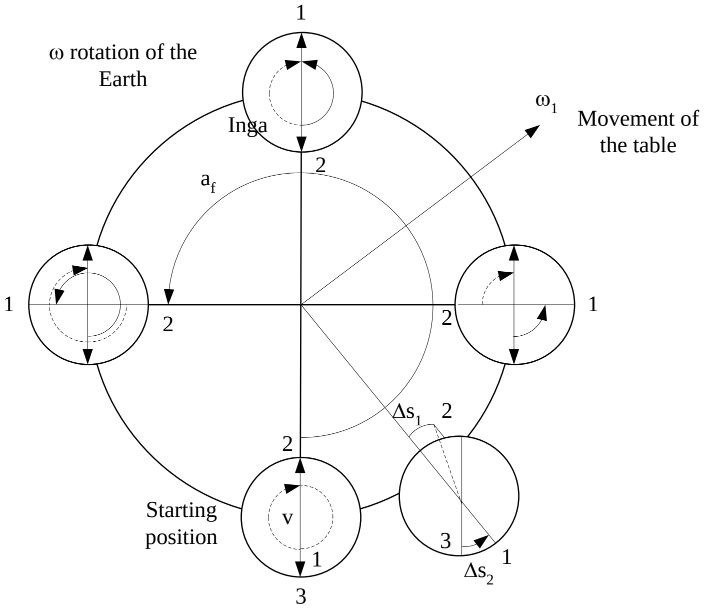


Figure 13. Phases of the pendulum movement [3]

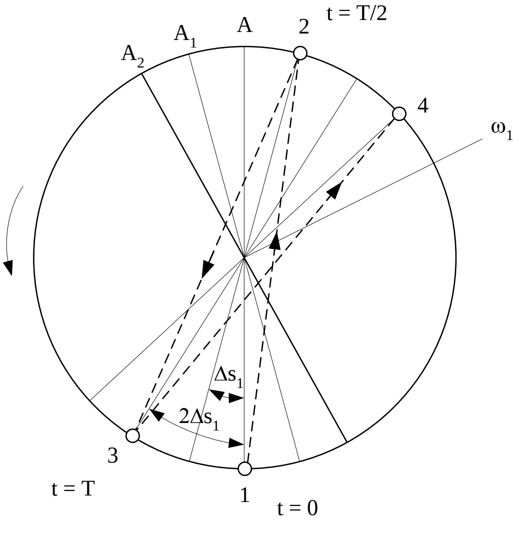


Figure 14. Effect of the Coriolis-force

In *Figure 15*, the changing of the location of the table and the pendulum through the rotation of the Earth can be followed. At starting of the pendulum movement (1) the time is zero (t = 0).

The time of the pendulum movement between point (1) and (2) is T/2. The value of the table movement can be calculated using *Figures 12–15* with the following data:

D – diameter of the circle followed by the end point of the pendulum [m]: $D = 2 \cdot A$,
A – amplitude of the pendulum movement [m],
ω – angular speed of the Earth [1/s]: $\omega = 7.29 \cdot 10^{-5}$,
ω_1 – angular speed of the table [1/s],
T – period of the pendulum movement [s]: T = 6.47 s,
$\phi = 48.1^\circ$.

$$\frac{\omega_1}{\omega} = \cos(90 - \phi)$$

$$\omega_1 = \omega \cdot \sin(\phi) = 5.43 \cdot 10^{-5}$$

Based on *Figure 13*:

$$\Delta s_1 = A \cdot \omega_1 \cdot \frac{T}{2}$$

The movement of the table during the period (T) is $2 \cdot \Delta s_1$.

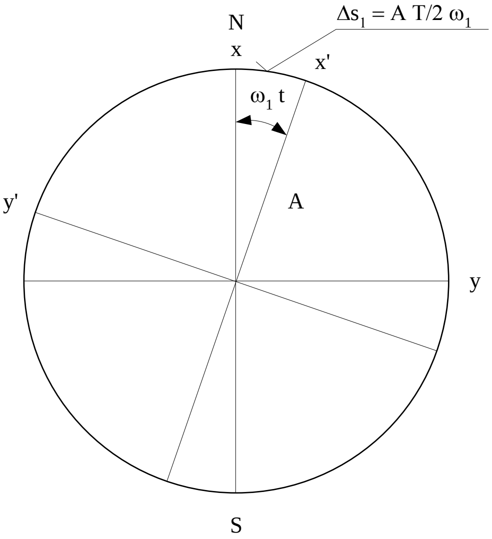


Figure 15. Location of the table and the pendulum during the rotation of the Earth

5.2. Coriolis-force

In a rotating reference frame, the pendulum movement diverges from the table in right direction at the Northern Hemisphere, caused by the rotation of the Earth *(Figures 13–15)*. The perpendicular movement is changing steadily from zero starting velocity. During short Δt times, to a close approximation, the Coriolis-force has to be taken as a constant value into consideration (see [5]). Acceleration of the Coriolis-force is

$$a_c = \frac{2 \cdot \Delta s}{\Delta t^2} \tag{22}$$

where

$$\Delta s = A \cdot \omega_1 \cdot \Delta t \tag{23}$$

$$\Delta t = \frac{A}{v} \tag{24}$$

Taking the above mentioned into account

$$F_c = 2 \cdot m \cdot v \cdot \omega_1 \tag{25}$$

where

F_c – Coriolis-force [N],
Δs – movement [m],
Δt – time [s]: $\Delta t = T/n$,
A – amplitude [m],
v – velocity of the pendulum [m/s],
m – mass of the pendulum [kg].

5.3. Effect of the Coriolis-force to the pendulum movement

The angular speed vector ω can be decomposed into a horizontal ω_2 and a vertical vector ω_1. The absolute values of them are

$$\omega_1 = \omega \cdot \sin\psi \tag{26}$$

$$\omega_2 = \omega \cdot \cos\psi \tag{27}$$

Suited to this, the Coriolis-force can also be decomposed into two components:

$$F_c = 2 \cdot m \cdot v \cdot \omega_1 + 2 \cdot m \cdot v \cdot \omega_2 = F_{c1} + F_{c2} \tag{28}$$

The first component means the force – arises on the pendulum moving in horizontal plane – tending to right direction which is perpendicular to the velocity of the Earth at the Northern Hemisphere. The second component is a vertical force in down or up direction, its effect is the changing of the weight of the moving mass.

The pendulum moving in horizontal direction is tending to right direction from its path because of the rotation of the Earth and the Coriolis-force. The amount of the difference can be calculated taking the values in *Figure 16* and *18* into consideration (L = 10.4 m, g = 9.81 m/s^2, m = 42 kg, G = m·g, L_0 = 10.38 m, π = 3.14, A = 0.669 m, $\omega_1 = 5.4275 \cdot 10^{-5}$ 1/s).

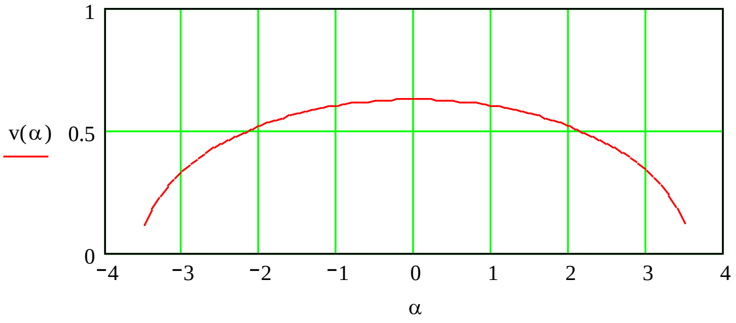


Figure 16. Velocity of the pendulum

Based on Figure 2, the energy equation of the pendulum movement can be described, from which the velocity of the pendulum *(Figure 16)*:

$$v(\alpha)=\sqrt{\left[10.4\cdot\cos\left(\alpha\cdot\frac{\pi}{180}\right)-10.38\right]\cdot 2\cdot 9.81} \tag{29}$$

From *Figure 17* the torque equations to point “0”:

$$M_1=\left(2\cdot m\cdot v\cdot\omega_1-m\cdot g\cdot\sin\alpha\right)\cdot L \tag{30}$$

$$M_2=m\cdot g\cdot k \tag{31}$$

$$\sin\alpha=\frac{k}{L} \tag{32}$$

$$k(\alpha)=L\cdot\sin\alpha \tag{33}$$

Arranging the equations above and applying that

$$M_1=M_2 \tag{34}$$

$$k(\alpha)=v(\alpha)\cdot\omega_1\cdot\frac{L}{g} \tag{35}$$

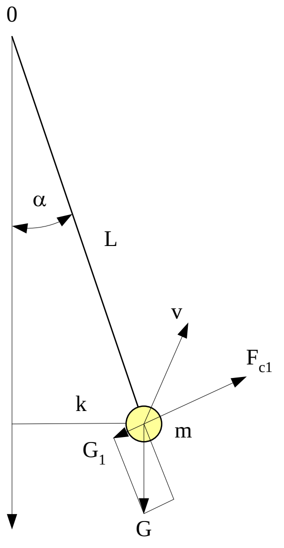


Figure 17. Forces on the pendulum

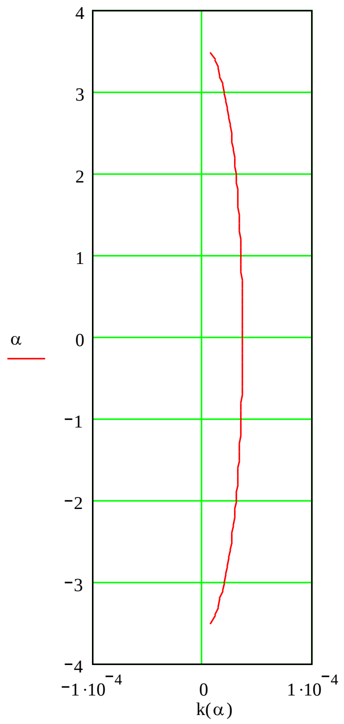


Figure 18. Deviation of the pendulum

Applying equation (29), the diagram presented in *Figure 18* is resulted. The distance from the origin is $k(0) = 3.64 \cdot 10^{-5} m$. We can see in Figure 18 that during the continuous motion, the pendulum does not go through the origin, but the deviation is so small that the observer cannot sense it and see a straight moving.

6. ANOTHER APPROACH OF THE MOVEMENT OF THE FOUCAULT-PENDULUM ABOVE THE TABLE

In this approach, we add the Coriolis-force to the equations of the pendulum movement in the reference frame, and we analyse only small-amplitude-swinging of the pendulum, when x/L and y/L are so small values, that their higher powers are neglected, only the first powers are taken into account. In this approach, the endpoint of the pendulum is moving in a horizontal plane (see [3]). Based on *Figure 1* and *12*:

$$\psi = 48.1^o \qquad \omega = 7.29 \cdot 10^{-5} \frac{1}{s} \qquad \omega_1 = \omega \cdot \sin\psi = 5.4275 \cdot 10^{-5} \frac{1}{s}$$

The equations of the motion:

$$\frac{d^2x}{dt^2} = 2 \cdot \omega \cdot \sin\psi \cdot \frac{dy}{dt} + \lambda \cdot x \tag{36}$$

$$\frac{d^2y}{dt^2} = -2 \cdot \omega \cdot \sin\psi \cdot \frac{dx}{dt} - 2 \cdot \omega \cdot \cos\psi \cdot \frac{dz}{dt} + \lambda \cdot y \tag{37}$$

$$\frac{d^2z}{dt^2} = -g + 2 \cdot \omega \cdot \cos\psi \cdot \frac{dy}{dt} + \lambda \cdot z \tag{38}$$

$$z = -L \qquad \frac{dz}{dt} = 0 \qquad \frac{d^2z}{dt^2} = 0 \qquad \lambda = \frac{-g}{L}$$

In equation (38), the component involving ω is very small related to *g*, so it is negligible

$$0 = -g - \lambda \cdot L \rightarrow \lambda = -\frac{g}{L}$$

Using this simplification, the equations of the motion are

$$\left.\begin{aligned} \frac{d^2x}{dt^2} - 2 \cdot \omega_1 \cdot \frac{dy}{dt} + \frac{g}{L} \cdot x = 0 \\ \frac{d^2y}{dt^2} + 2 \cdot \omega_1 \cdot \frac{dx}{dt} + \frac{g}{L} \cdot y = 0 \end{aligned}\right| \tag{39}$$

The equations above can be coupled in one complex equation:

$$u = x + i \cdot y \tag{40}$$

Suited to (40), the equation of the motion is

$$\frac{d^2u}{dt^2} + 2 \cdot i \cdot \omega_1 \cdot \frac{du}{dt} + \frac{g}{L} \cdot u = 0 \tag{41}$$

Taking *Figure 15* into account

$$u' = x' + i \cdot u' = u \cdot e^{i \cdot \omega_1 \cdot t} \tag{42}$$

After simplification and taking the starting conditions into consideration

$$x = x' \cdot \cos(\omega_1 \cdot t) + y' \cdot \sin(\omega_1 \cdot t) \tag{43}$$

$$y = -x' \cdot \sin(\omega_1 \cdot t) + y' \cdot \cos(\omega_1 \cdot t) \tag{44}$$

$$x' = x_1(t) \cdot \cos(\omega_1 \cdot t) - y_1(t) \cdot \sin(\omega_1 \cdot t) \tag{45}$$

$$y' = x_1(t) \cdot \sin(\omega_1 \cdot t) + y_1(t) \cdot \cos(\omega_1 \cdot t) \tag{46}$$

These equations mean that the axes x’ and y’ are rotating in a horizontal plane with ω_1 angular speed, related to the observing *x-y* system. Transformations and simplifications can be seen in reference [1].

In (x’, y’) system, if t = 0, then

$$x' = A \quad y' = 0 \quad \frac{dx'}{dt} = 0 \quad \frac{dy'}{dt} = A \cdot \omega_1 \quad a = A = 0.669m$$

$$x' = a \cdot \cos\left(\sqrt{\frac{g}{L}} \cdot t\right) \qquad y' = b \cdot \sin\left(\sqrt{\frac{g}{L}} \cdot t\right)$$

$$\sqrt{\frac{g}{L}} = \omega_0, \quad \frac{b}{a} = \omega_1 \cdot \sqrt{\frac{L}{g}} \Rightarrow b = a \cdot \frac{\omega_1}{\omega_0} = 0.6 \cdot \frac{5.4275 \cdot 10^{-5}}{0.971} = 3.739 \cdot 10^{-5}$$

Applying the above described values and substitute them into the (43) and (44) equations, the (47) and (48) equations are obtained, which describes the pendulum movement as a function of the swinging period (see *Figure 19* and *20*).

$$x(t) = A \cdot \left[\cos(\omega_1 \cdot t) \cdot \cos(\omega_0 \cdot t) + \frac{\omega_1}{\omega_0} \cdot \sin(\omega_1 \cdot t) \cdot \sin(\omega_0 \cdot t)\right] \tag{47}$$

$$y(t) = A \cdot \left[\frac{\omega_1}{\omega_0} \cdot \cos(\omega_1 \cdot t) \cdot \sin(\omega_0 \cdot t) - \sin(\omega_1 \cdot t) \cdot \cos(\omega_0 \cdot t)\right] \tag{48}$$

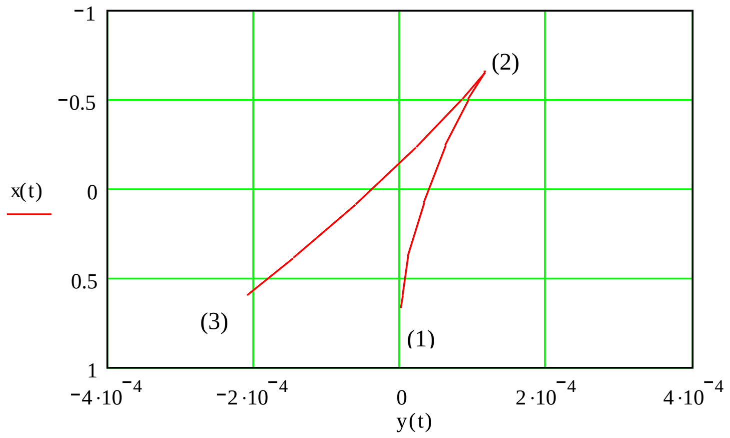


Figure 19. One single period of the pendulum movement
(1) – start of the pendulum, y(0), (2) – y(T/2) = $1.054 \cdot 10^{-4}$, (3) – y(T) = $-2.107 \cdot 10^{-4}$

Figure 19 and *20* present the movement of the pendulum in (x’, y’) plane, where L = 10.4 m, g = 9.81 m/s^2, A = 0.669 m, $\omega_1 = 5.4275 \cdot 10^{-5}$ 1/s, $\omega_0 = 0.971$ 1/s, $\omega = 7.29 \cdot 10^{-5}$ 1/s, T = 6.47 s.

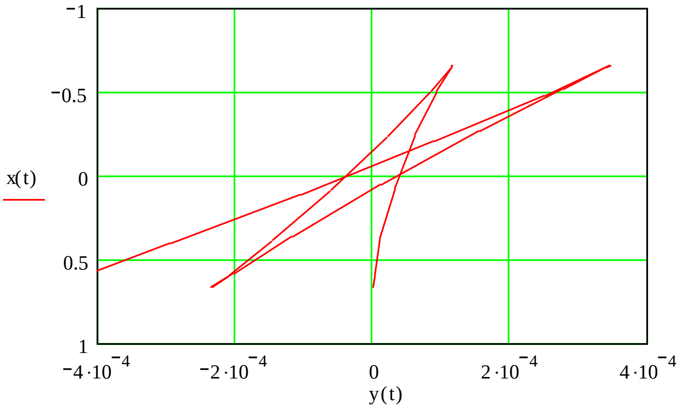


Figure 20. Two periods of the pendulum movement (y(T/4) = 3.353 · 10^{-5})

Transforming equations (45) and (46), *Figure 21* is obtained, which shows that the pendulum is moving along an elliptic line (diagram is not scaled).

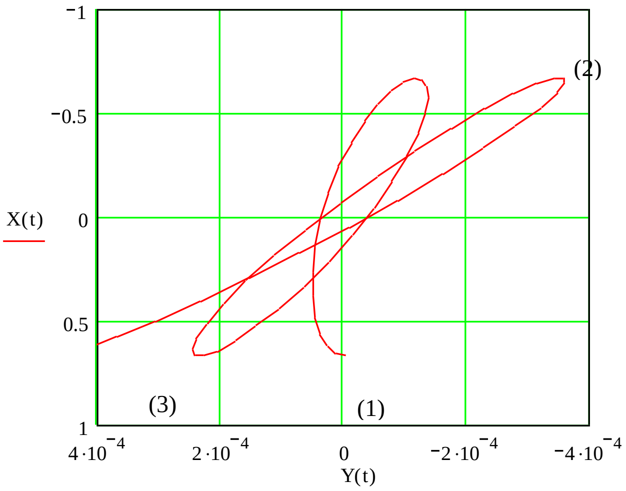


Figure 21. Elliptic characterisation of the pendulum movement
(1) – start of the pendulum, Y(0), (2) – Y(T/2), (3) – Y(T)

In *Figures 19–21*, the pendulum is moving in (x’, y’) plane. The pendulum is horizontally rotating with ω_1 angular speed, where a = 0.669 m, b = $3.74 \cdot 10^{-5}$, $\omega_1 = 5.4275 \cdot 10^{-5}$ 1/s, $\omega_0 = 0.971$ 1/s, $\omega = 7.29 \cdot 10^{-5}$ 1/s, T = 6.47 s.

$$x_1(t) = a \cdot \cos(\omega_0 \cdot t) \tag{49}$$

$$y_1(t) = b \cdot \sin(\omega_0 \cdot t) \tag{50}$$

$$X(t) = x_1(t) \cdot \cos(\omega_1 \cdot t) - y_1(t) \cdot \sin(\omega_1 \cdot t) \tag{51}$$

$$Y(t) = x_1(t) \cdot \sin(\omega_1 \cdot t) + y_1(t) \cdot \cos(\omega_1 \cdot t) \tag{52}$$

Based on the figures the next thesis can be described: *at a given geographical attitude „ψ" of the Earth, the pendulum movement – in case of small amplitudes – follows an elliptic line, and the axes of the ellipse are rotating in a horizontal plane with ω_1 angular speed in north-east direction at the Northern Hemisphere (see* Figures 19–21*).*

Figure 21 is not scaled, but it is suitable to demonstrate the elliptic movement of the pendulum. Based on the equations of Müller [3], and the previously defined values (L = 10.4 m, g = 9.81 m/s^2, a = 0.669 m, $\omega_1 = 5.4275 \cdot 10^{-5}$ 1/s, $\omega_0 = 0.971$ 1/s, T = 6.47 s)

$$b = a \cdot \omega_1 \cdot \sqrt{\frac{L}{g}} = 3.739 \cdot 10^{-5} \qquad \frac{a}{b} = 1.995 \cdot 10^4$$

Figure 22 shows the movement of the pendulum during the time "T". The movement has elliptic character, but the smaller axis of the ellipse is so small that the observer cannot sense it and see a straight moving.

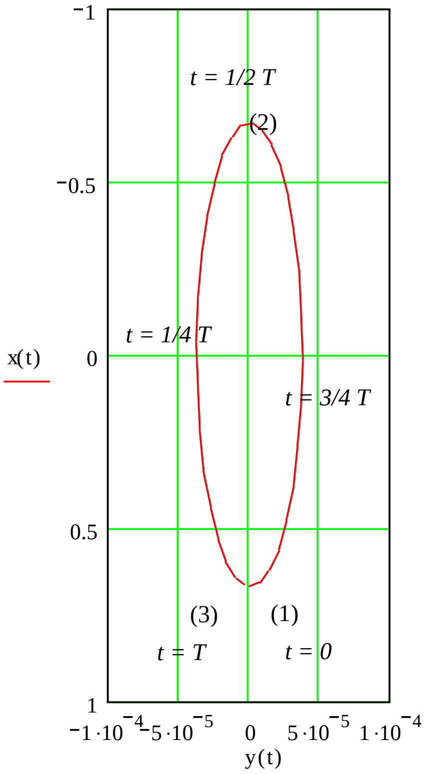


Figure 22. Pendulum movement during the time "T"

7. SUMMARY

Jean Foucault's strand-pendulum, which was used to demonstrate the rotation of the Earth, can help to understand the behaviour of swinging bodies and the rules which influence their movement. As the material handling uses many machines, in which the units can swing during transport or loading, the analysis of the pendulum movement can result many important data for the design of the handling machines and processes. The theoretical method described by the author was confirmed by the data and measuring values of the Foucault-pendulum built in the main reception hall of the University of Miskolc. A possible sequel can be the analysis of bridge cranes, where the pendulum movement directly influences the operation parameters and causes operation problems. It is especially true for automated bridge cranes.

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BRING ME: SUSTAINABLE URBAN DELIVERY SERVICE FOR THE CITY OF GRAZ

WOLFGANG TRUMMER[1]–NORBERT HAFNER[2]

Abstract: A large proportion of urban transport results on private shopping. Alternatives to operate the first-/last-mile-logistics for urban shopping in a sustainable manner are often missing. In August 2014 a new, environment friendly and sustainable delivery service for City center of Graz started – named “bring mE”. With this service, private shoppers have the opportunity to get their purchases delivered by cargo bicycles. The task of the ITL (Institute of Engineering Logistics) was to ensure a successful implementation of the delivery. For this purpose, the delivery service was evaluated after a period of 9 months and necessary improvement measures were derived. The result of the study shows that individual stores used the service for about 100 times during the period of evaluation. Furthermore, specific purchasing periods (Christmas, Easter) provided the highest usage for the delivery service. The conclusions derived showed the high potentials of the logistic solution.

Keywords: *City Logistics, Last Mile Logistics, Sustainable Logistics*

1. INTRODUCTION

1.1. “bring mE” delivery service

Traffic congestion in urban areas leads to an increasing stress on people and nature. A large part of urban transport accounts on private shopping [1]. Social trends, such as online trade and shopping centers in the city limits, contribute to an increase in traffic and negative environmental consequences of CO2 emissions, fine dust pollution, etc. [2].

Part of this problem is a missing offer of alternatives to operate the last-mile-logistics in a sustainable manner. Solutions for sustainable customer delivery services in urban areas are not new, but still form a niche [3]. Most of these services are set by individual stores to their customers and often performed with “normal” combustion engine vehicles. In the City of Graz, with its historic center, it is a general scope to reduce delivery traffic for a long time of period. It is also important to support the traders and trading companies in the center and in total to make the urban city center more attractive for living [4].

In August 2014 a sustainable, user-friendly delivery service started in the City of Graz. The name of the delivery service is “bring mE” *(Figure 1)*. The service aims to private customers in the central urban area to provide sustainable delivery within the meaning of last-mile logistics. The delivery within the city is carried out with eco-friendly vehicles (e-cargo bikes, e-pedelecs) [5], [8].

Figure 1. Official logo of “bring mE” delivery service [6]

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The delivery service was implemented together with municipal, scientific and private partners. Furthermore, the implementation of the project was supported by the international SMARTSET project, co-funded by the Intelligent Energy Europe Program of the European Union [7]. The SMARTSET project developed and showed how freight transport in European cities and regions can be made more energy-efficient and sustainable by a better use of freight terminals *(Figure 2)*.

Figure 2. Partners meeting of project SMARTSET in the City of Graz presenting the sustainable "bring mE" delivery service [8]

Thus, the individual motorized traffic should be reduced within the city center and the opportunity to do shopping activities on foot, by bike or by public means of transport should be given [9]. Therefore multiple benefits are achieved with the services of "bring mE": Ecological delivery with e-vehicles and change of consumer behavior using public transport as well as attractiveness of downtown commerce and the entire urban habitat [10], [11].

1.2. Evaluation of the service

In order to guarantee a successful operation of the delivery service, ITL carried out an accompanying evaluation of the service. The evaluation of the service was funded by the Austrian Research Promotion Agency (FFG). With the evaluation, the concrete needs for a delivery service were collected by customers and shops. Furthermore, the economic development of the service was tested during the test phase. From the findings of the evaluation, improvement measures for the design and execution of the service were derived. The evaluation took place after a 9-month period of customer delivery service.

The content of this paper focuses on the following investigated areas:

- Business model of "bring mE".
- Statistical analysis for the evaluation period.
- Evaluation and improvement measures.

2. BUSINESS MODEL OF “BRING ME” DELIVERY SERVICE

2.1. Objective of service

The service model defined within “bring mE” was conceived in the preliminary project “eCiLo” [5], funded by the Austrian Research Promotion Agency (FFG), and can be described as follows: The delivery service serves the delivery of purchased goods from shop to retail customer (B2C). Deliveries of all kinds and sizes except refrigerated goods are supplied. The pricing of the service depends on the size of the goods and the distance of the delivery. For the simple design of the service allocation, three size categories and two delivery zones are defined.

The service can be ordered in the time window between 8:00 and 17:00. The subsequent collection of the goods in the shop takes place in the period between 17:00 and 18:00 and the delivery takes place in the time window between 18:00 and 21:00. To meet individual customer requirements, two different delivery time windows are available. The first time window extends between 18:00 and 20:00 and the second from 19:00 to 21:00. For an extra charge, delivery outside of these delivery times is possible.

In detail, the process of the delivery service can be described as follows *(Figure 3)*:

1. Service order by customer.
2. Service registration done by shop assistant.
3. Order management online with “bring mE” internet service portal (www.bring-me.at/).
4. Planning of collection and delivery route done by “bring mE” logistics dispatcher.
5. Collecting goods from the shop done by “bring mE” deliverer with cargo bikes.
6. Delivery of goods done by “bring mE” deliverer.

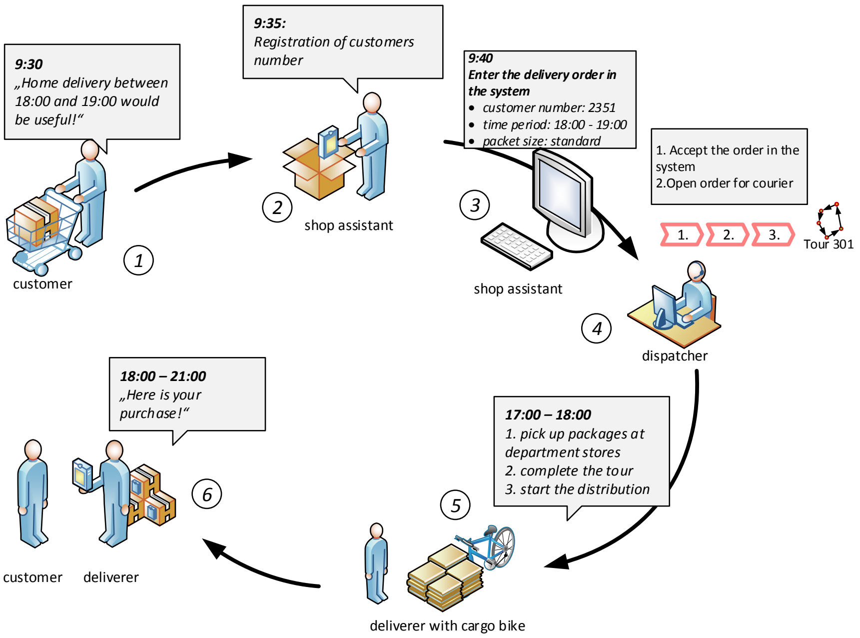


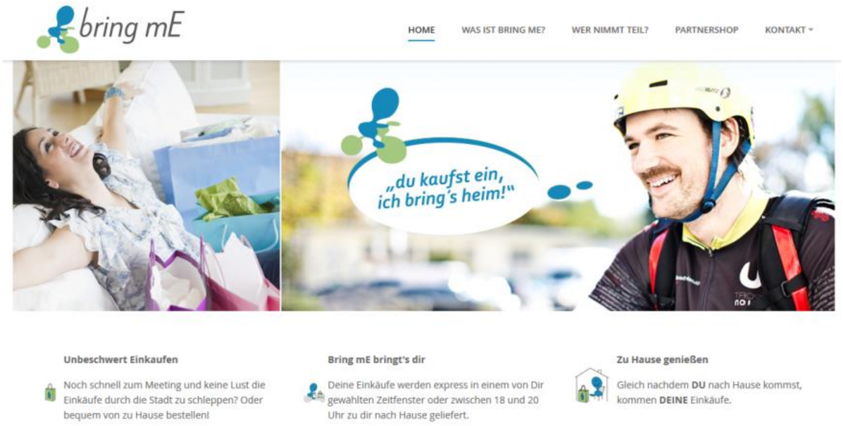
Figure 3. Service model of delivery service of “bring mE”

2.2. Resources and tour planning

The execution of the deliveries is done by messengers of the association “Veloblitz”. There are about ten couriers available every day, which carry out the delivery tours. Three different cargo bicycles are available for the couriers. Each cargo bicycle has a loading capacity depending on the package sizes of 6 to 12 packages. The transport of parcels is carried out mostly in direct transport routines without intermediate storage of the goods.

2.3. Partners and pricing

The launch of the service took place in August 2014. The service was initially started with ten shops. The service marketing started especially by website, magazines, posters, folders and stickers *(Figure 4)*.



Unbeschwert Einkaufen

Noch schnell zum Meeting und keine Lust die Einkäufe durch die Stadt zu schleppen? Oder bequem von zu Hause bestellen!

Bring mE bringt's dir

Deine Einkäufe werden express in einem von Dir gewählten Zeitfenster oder zwischen 18 und 20 Uhr zu dir nach Hause geliefert.

Zu Hause genießen

Gleich nachdem **DU** nach Hause kommst, kommen **DEINE** Einkäufe.

Figure 4. Website of delivery service “bring mE” [6]

The pricing of the service is according to delivery distance and package size. This results in four different price categories, which makes the pricing easy to understand. The service is payed either from the store or the customer. The customer pays for the service on receipt of the package. Delivery takes place throughout the City of Graz *(Figure 5)*.

Figure 5. Definition of delivery areas of “bring mE” within the City of Graz

Delivery zone I comprises the inner city area (districts 1 to 6), the delivery zone II comprises the outer city area (districts 7 to 17).

The following package sizes are defined within the service:

- Small: A4 cards with 32 × 23 × 30 cm / max. 10 kg;
- Medium: packing case with 58 × 35 × 30 cm / max. 20 kg;
- Special format: no restrictions.

All of the ten shops participating in the delivery service are located in the center of Graz: seven shops are located in the first district, three shops are located close to the first district. This simplifies the collection of goods within the pick-up routines between 17:00 and 18:00. Customer acquisition is done exclusively by the shops. The registration card includes name and address of the customers *(Figure 6)*.

Registrierung
Zustellservice bring mE
„du kaufst ein, ich bring´s heim!"

Kunden-Nr.
0815

Vorname

Nachname

Straße, Hausnummer

PLZ Ort

Telefonnummer

E-Mail-Adresse (optional)

Es gelten die AGB auf www.bring-me.at,
die Sie mit Ihrer Unterschrift akzeptieren.

Datum, Unterschrift

bring mE

Kunden-Nr.
0815

Ihre bring mE Kundenkarte

„du kaufst ein,
ich bring´s heim!"

Hotline
T 0316/349999
www.bring-me.at

Ein Projekt von:

smartset GRAZ

Figure 6. Customer registration form

3. STATISTICAL ANALYSIS FOR THE EVALUATION PERIOD

Official start date of delivery service was in August, 2014. The customer and order data were analyzed within the evaluation period from 1st of September, 2014 to 31th of May, 2015 (corresponds to 273 calendar days and approximately 220 shopping days). Data collection took place via personal interviews and database extracts from the delivery service provider.

3.1. Customer development

Within the evaluation period, approximately 130 persons registered at the "bring mE" delivery service. The analysis of the number of new customers after calendar months in the evaluation period *(Figure 7)* shows that most customer registrations took place during the period before Christmas. The maximum number of new customer registrations was therefore for December 2014 (25% of total amount of new customers), the minimum was in April 2015 (4% of total amount of new customers).

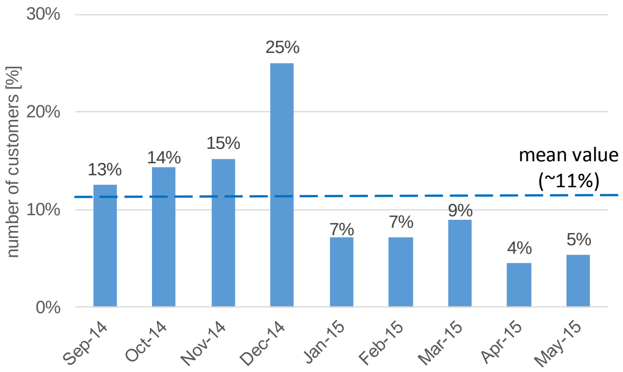


Figure 7. Number of new customers during the period of evaluation (September, 2014 to May, 2015)

3.2. Service Orders

3.2.1. Order volume for calendar months

The analysis of the order volume after calendar months shows that the purchasing period before Christmas (November and December) and Easter (March) provided the highest usage for the delivery service. The maximum of deliveries per month were in December (24% of total amount), and the minimum in April (5% of total amount). In total, the service was ordered about 150 times during the period of evaluation *(Figure 8)*.

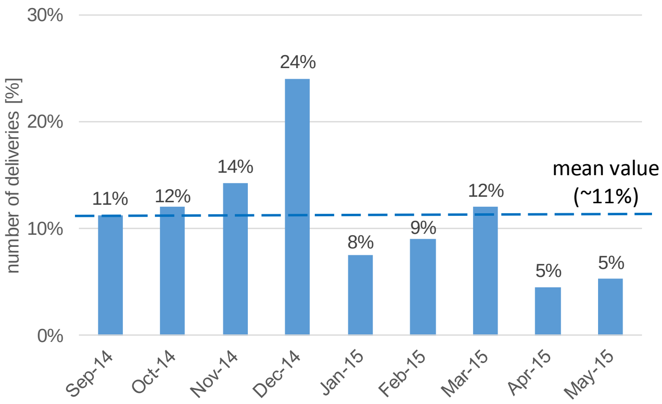


Figure 8. Number of deliveries during the period of evaluation (September, 2014 to May, 2015)

3.2.2. Order volume for weekdays

The evaluation of the order volume by weekday shows that the service is used primarily in the middle of the week (Wednesday, 22% of total amount) and not – as expected – on weekend (Friday or Saturday). In total, orders from Friday and Saturday (weekend shopping) account for 30% of total orders per week *(Figure 9)*.

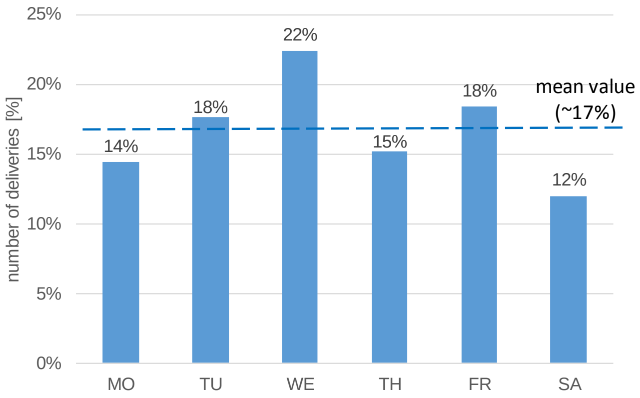


Figure 9. Percentage distribution of deliveries done per weekday (Monday to Saturday)

3.2.3. Order volume according to individual customers

About 13% of all customers used the service several times during the period of evaluation: 10% of the “bring mE”-customers used the service exactly two times and 3% of the customers used the service more than two times *(Figure 10)*. For example, the service was used six times by one specific customer.

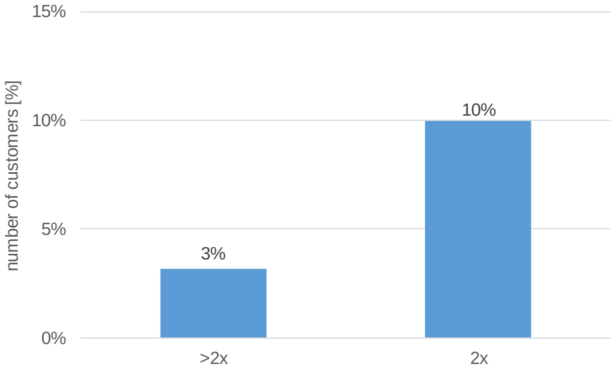


Figure 10. Number of multiple use of the service from individual customers

3.2.4. Order volume by package size

Three different package sizes were defined within the delivery service (see chapter 2.3). The package size within the period of evaluation variates as follows *(Figure 11)*:

- 38% of delivered packages are “small” size;
- 44% of delivered packages are “medium” size;
- 18% of delivered packages are “special” size.

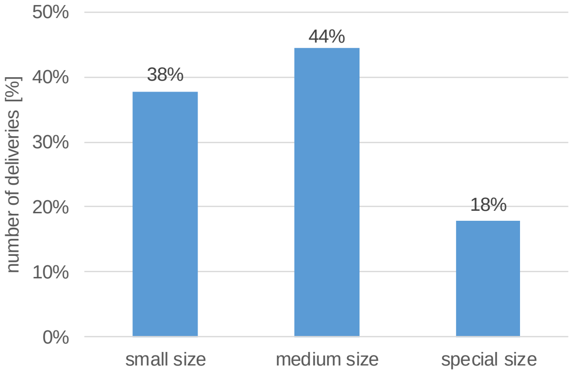


Figure 11. Percentage distribution of package sizes

3.2.5. Order volume by stores

Within the evaluation period the service was primarily used within four out of ten shops. Figure 12 shows the percentage distribution of delivery orders by single stores: One specific store caused 73% of total amount of deliveries.

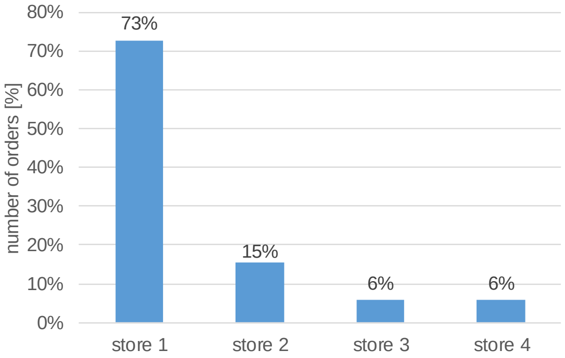


Figure 12. Percentage distribution of delivery orders of individual stores

Sector allocation of the listed stores:

- Store 1: household products store;
- Store 2: book store;
- Store 3: giftware store;
- Store 4: health care supply store.

The example of Store 1 shows, that a high customer demand for the service can be created by appropriate self-initiative of the shops (online advertising, store pays the costs) and depending on the shopping goods (medium size and weight). In many cases, an existing delivery service offered by the shops (e. g. by taxi) can be substituted by the sustainable “bring mE” service without any additional costs.

3.3. Cost absorption and delivery time

3.3.1. Cost absorption

The payment of the service is done either by the stores or the customers. Some stores assume delivery costs, usually depending on the purchase sum. For example, one of the partner stores offers a free delivery for regular clients in the City of Graz. The distribution of cost absorption for the deliveries show the following result *(Figure 13)*:

- 93% of deliveries were paid by stores;
- 7% of deliveries were paid by customers.

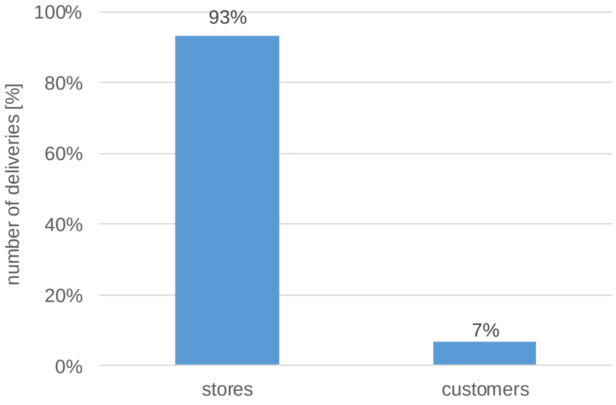


Figure 13. Percentage distribution of cost absorption for the delivery service

3.3.2. Delivery time

The following figure shows the distribution of the delivery time windows preferred by the customers *(Figure 14)*:

- 77% of deliveries were done in the time window between 18:00 and 20:00;
- 21% of deliveries were done in the time window between 19:00 and 21:00;
- 2% of deliveries were done in a separate time window (customer-determined).

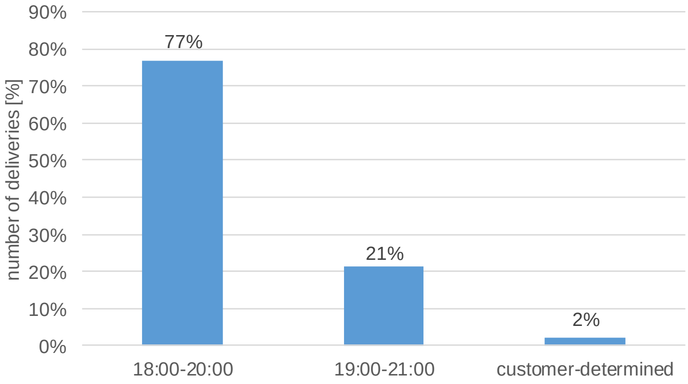


Figure 14. Percentage distribution of used time window for deliveries

4. EVALUATION AND IMPROVEMENT MEASURES

4.1. Current order situation

The low participation of the majority of “bring mE” partner stores (only 4 out of 10 stores used the service within the period of evaluation, see chapter 3.2) is one of the main problems, why the service has a relatively low order frequency. The analysis shows that there is no effect of order growth in the evaluation period despite rising customer stocks.

From the analytic results it is evident, that one single store is the driving force of the existing service within the evaluation period (with 73% of total amount of orders, see chapter 3.2). The extrapolation shows that, in case of a number of twenty stores with a similar request of the delivery service, there is a capability of about 2000 orders during the evaluation period. This would correspond to a weekly volume of approximately 50 orders.

4.2. Network of partners

Existing delivery services in shops, e. g. by taxi, can be optimally replaced by the “bring mE” delivery service. The service is especially interesting for shops located in the pedestrian zone (restricted accessibility by car), which have a medium-sized range of goods in medium price segment (product price about EUR 100). To enlarge their services, stores can offer the customer a cost-free delivery service (about 93% of the orders are paid by the shops, see chapter 3.3), in exchange it increases customer loyalty. For example, one of the stores offers its regular customers a free delivery in the City of Graz.

The shops in which the service is currently offered are selling mainly consumer goods and luxury goods, but fewer convenience products. The consequence is that the individual (at “bring mE” registered) customers enter these shops irregularly, which leads to an irregular use of the service by these costumers.

4.3. Pricing

Stores may expand their business services by offering a sustainable delivery service. The uncomplicated service and pricing structure creates transparency for stores and customers and reduces emotional barriers (too cumbersome, too expensive) when using the service.

The prices for the service appear relatively narrowly from economic point of view (statement from delivery service provider). This is why it is questionable whether the service can be operated profitably in case of insufficient capacity utilization or how the pricing will be defined in the future. Especially for packages of oversize format, it might be useful to define a further classification of prices.

In general, however, the more stops per tour can be realized, the better the utilization of the cargo bikes and the higher the resulting profit margin per stop. The problem which arises in the implementation phase of such services is that due to the missing awareness, no high order volume is to be expected.

4.4. Derivation of specific improvement measures

In order to increase the success of the service, the following improvement measures were defined in cooperation with the project partners, which were implemented within the remaining project term:

- Marketing measures
    - Gain additional partnerships for active participation (especially leading stores in the City of Graz).
    - Extended roll-out of the service driven by the City Management of Graz and initiatives to increase the awareness level of the service.
    - Special service offers for main shopping seasons during the year (e. g. Christmas shopping, Easter shopping).
- Strategic measures
    - Link the service with online shopping portal of the City of Graz.
    - Apply for funding of the service (until level of awareness is reached).
- Organizational measures
    - Simplify online forms, registration cards and order cards.
    - Create the opportunity to offer the service for all stores in the City of Graz through an open-ended Internet portal.

5. SUMMARY

Logistics services for the delivery of essential goods are increasingly developing into successful business models in European cities. These services form an important part in the area of sustainable last mile freight traffic [3]. The demands of the European Union on the reduction of fuel emissions in urban areas [12] can only be achieved by sustainable transport solutions. Here projects for sustainable urban logistics play an important role and are supported more and more from European support programs (like SMARTSET [7], ELTIS [16]) and national funding initiatives (Austrian Climate and Energy Fund [13]).

Meanwhile, the “bring mE” service is operating for over three years. Some measures were implemented for the economic success of the service due to the adaptation recommendations of the ITL. For example, the cost model was adapted to standardize and facilitate the pricing. The City Management of Graz applies the service on its homepage and promotes for example free deliveries in the Christmas business [14]. In addition, the Internet portal of “bring mE” for business registration was expanded and simplified. In the meantime, over 50 partner shops are actively involved in the delivery service and some of them offer a free delivery service as extended customer service. For the City of Graz, the service “bring mE” is a flagship initiative in the field of realizing sustainable urban logistics [8], [15].

The customer and order data were analyzed within the evaluation period from 1st of September, 2014 to 31th of May, 2015 (corresponds to 273 calendar days and approximately 220 shopping days). Additional analyzes (periods) should be added to increase the maturity level of further improvements.

The results of the project show the enormous potential of sustainable logistics solutions in urban areas. At the ITL, this potential has been recognized and we will focus on topics such as e-based logistics, sustainable urban cable cars, etc. in current and future research projects.

Acknowledgments

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RISK MANAGEMENT IN LOGISTICS NETWORKS: AN OVERVIEW OF THE FIELD AND SOME NOVEL PERSPECTIVES

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Abstract: The publication covers a topic that is gaining more and more significance, namely the area of risk management in logistics networks. This domain became a focus of attention lately for a number of reasons, but most importantly because of the increasing sensitivity of global supply chains to various disturbing effects. Another important reason is the trend of digitalization, which naturally increases the significance of information-based collaboration inside the logistics networks, but it also raises more questions regarding the reliability of the participating elements. Taking into account the previous considerations, the publication tries to provide a comprehensive picture about the current status of the field. Based on the survey of the related literature, it introduces the background and the significance of the topic while also presents the most important trends, the frequently used approaches and a number of related examples. Moreover, partly based upon the conclusions drawn from the literature review, a novel approach for solving the problem is also proposed that could be successfully utilized in the future.
Keywords: *logistics networks, risk management, literature review*

1. THE EVOLUTION AND SIGNIFICANCE OF MODERN LOGISTICS NETWORKS

Logistics networks have been playing an important role in the economy for a long time, though their significance became truly obvious in the last decades. This of course is largely connected to the strengthening of such trends as the expansion of multinational companies, the continuous development of global supply chains or the growing dominance of global markets, as these processes are all largely based on the effective operation of logistics networks. Meanwhile, the continuous emphasis on cost reduction significantly increased the role of logistics outsourcing, which greatly supported the expansion of the logistics service providers as well [1].

It is very important to emphasize that the field of e-commerce also played a crucial role in the evolution of modern logistics networks, especially in the last two decades. While the business sector has been using computer networks for the handling of transactions since the 1970-s and the first EDI applications also appeared during this time, the true advancement was of course came with the spread of the internet and its related technologies. Accordingly, the first e-marketplaces in logistics also appeared in the early 1990-s, first naturally in the area of freight-forwarding (for example NTE or DAT), as it is described in the comprehensive work of Nandiraju and Regan [2]. These were followed in short order by a number of such marketplaces that provided more complex value-added services, thereby giving a glimpse of a future which is dominated by internet-based services (typical examples were FreightMatrix, Transplace or Nistevo, the latter was being also one of the first examples for a collaborative network) [2]. A high-level working schematic of a typical auction-based e-marketplace in the area of freight-forwarding can be found in *Figure 1*.

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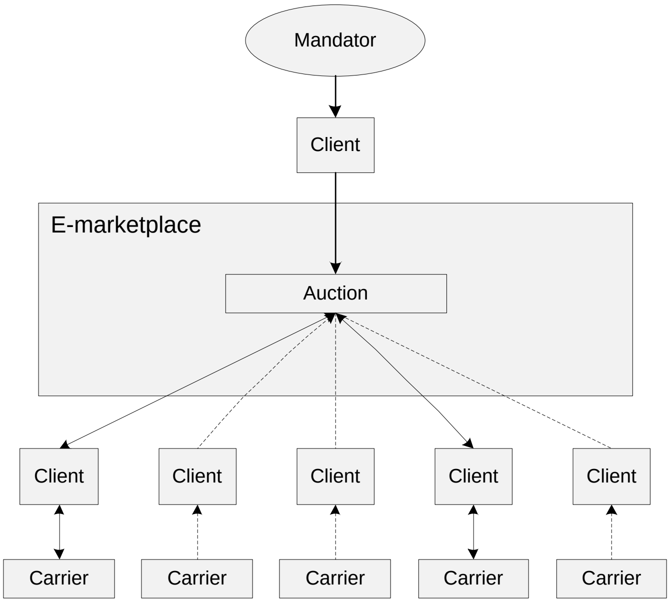

Figure 1. High-level representation of an e-marketplace in the area of freight-forwarding, a typical e-commerce based component of modern logistics networks (Source: own work)

From this point forward the developments followed each other at an even faster pace, which was also fueled by the rapid unfolding of e-commerce. The latter also increased the need for smaller but more frequent shipments (especially for parcel delivery), while the reduction of lead times also became an even more important issue (in many cases, one-day and same-day delivery became a standard practice). All of these developments made it even more necessary to create and maintain effective distribution networks, together with modern e-commerce based supply chains. The description of these processes can be found in a large number of publications. A few examples include the works of Joong-kun, Ozment and Sink [3], Huppertz [4], Foster [5], Harrington [6] and Hill [7]. A good description can also be found in the edited by Gubán [8]. The formation of modern distribution networks further increased the need for the outsourcing of logistics services, thereby supporting the continuous expansion of 3PL („third party logistics") providers. This latter observation can also be found in many sources, like in the already mentioned [3] and [8], or for example in the more economics-oriented publications of Deckmyn [9], Scheraga [10] and Kroll [11]. It is also important to note that in the United States, in parallel with (and partly even before) the previous processes, a deregulation process had also been taken place that allowed the emergence and expansion of 3PL providers in the freight-forwarding industry (this is also described in [2], or for example in the related work of Menon, McGinnis and Ackerman [12]). Therefore, it can be seen that the intensification of the global trends, the increasing role of logistics outsourcing, the spread of 3PL providers, and finally the rapid expansion of e-commerce and the use of internet technologies have all contributed to the rise of modern logistics networks through a mutually strengthening way. Of course, the role of risk management in these networks increased in parallel with the previous processes, especially in the supply chains of multinational companies.

The effects of the so called "fourth industrial revolution" on the logistics networks also have to be discussed, as this new paradigm has the potential to cause fundamental changes in the entire industry and economy. Through the widespread application of high level automation, the extensive use of machine to machine communication and real time status monitoring, moreover through the analyzation of the large amounts of information generated by the previous techniques, the fourth industrial revolution could open up entirely new possibilities for the manufacturing companies. For example, it could make it possible to fulfil wide-ranging customer expectations in a flexible way, while at the same time it could also achieve reduced lead times, significantly reduced costs and nearly loss free operation. A detailed description of these possibilities can be found for example in the works of Illés et al [13], [14], in the work of Bányai [15] and in other publications which the latter wrote with his co-authors [16], [17], [18], in the work of Gubán et al [19], and also in the related papers of Tamás [20], [21]. Moreover, the increasingly flexible automation technologies could also increase the role of the holonic manufacturing systems, which are also based on properly organized supply chains [22]. However, the effective organization and operation of logistics networks will have an even greater importance in the more general sense as well, due to the fact that an increased level of transparency and information sharing will be required from the logistics service providers by both the end users and the manufacturing companies. Overall, it can be stated that because of these fundamental changes, the significance of collaborative logistics networks – together with the so-called "virtual enterprises" – will notably increase, which will provide an even greater role for performance measurement and risk management in the related supply chains.

2. RISK MANAGEMENT IN SUPPLY CHAINS

As it was mentioned before, risk management already plays a vital role in one of the most characteristic type of logistics networks, the supply chain. This is very well represented by the fact that the number of related publications between 2000 and 2015 had been tripled based on ScienceDirect, moreover this growth became most intensive since 2010, according to the work of Ziółkowska, Gorzeń-Mitka, Sipa and Skibiński which summarizes some of the main challenges in supply chain management [23]. However, it also has to be noted that while a large number of publications concentrate on the identification of risk sources, a relatively smaller number of them provides quantitative measurement and analytical tools for the precise evaluation of these factors [23]. Besides, it also has to be seen that the field of Supply Chain Risk Management (SCRM) can still be considered relatively new, therefore a large number of different approaches exist both from the perspectives of categorization and analyzation, as it is described in the survey made among the researchers by Sodhi, Son and Tang [24]. What these facts certainly prove however is that there are significant research opportunities in this field.

In general, it can be stated that among the various risk sources in the supply chain, the transportation delays play an outstanding role, together with the changing demand, the asymmetric information flow and inadequate level of supply chain integration (see the already mentioned [23], moreover the SCRM related publication of Wieland and Wallenburg [25], and also that of Wang [26]). However, there are significant differences of opinion regarding the selection of the areas and the main aspects of risk management in the supply chain. In [24] the authors found the following interpretations for the definition of SCRM: according to 33,3% of the researchers SCRM focuses on the stochastic relationship between supply and demand; 31% of them thinks that it mainly deals with the operational risk factors in the supply chain; 19% of the researchers think that it analyzes the probabilities for rare but significant events; 14,3% of them believe that it deals with yet unknown risk factors; 11,9% of them think that if focuses on the disruptions and catastrophes affecting the supply chain; 7,1% of them believe that it analyzes the risk factors inherent in the supply chain strategy; 4,8% think that it concentrates on developing new probability-based methods; finally, another 4,8% of them believe that it deals with the related financial risks. From the previous, it can be seen that the definition of the field is far from being unified. However, according to [24], the two most widespread approaches are by far the evaluation of the supply risks and the analysis of the operational (logistics related) risk factors in the supply chain.

As in the case of defining the field, there is also a large variation among the utilized techniques as well. A good overview of the latter can be found in the comprehensive work of Ghadge, Dani and Kalawsky [27], which categorizes the majority of methods utilized in SCRM. In this publication, the authors identify three main categories, namely qualitative (54,17% of the examined cases), quantitative (36,66% of the examined cases) and mixed (9,17% of the examined cases) methods. Qualitative methods include case studies, data analysis and conceptual theories, among others. In case of quantitative methods, the majority of them is made up by the modeling techniques used in operations research (OR). According to the authors, these can be further classified into hard (14,17% of the examined cases) and soft (5,83% of the examined cases) methods. Hard OR methods include linear programming, game theory, queuing theory and Markov process [27] [28], while soft OR methods include the use of SWOT/POST analysis, viable systems model, scenario planning and a number of other techniques [27]. Besides the methods of operations research, the use of simulation, probability and statistics, and stochastic programming also belong to the quantitative group, while mixed methods naturally cover those that arise from a combination of techniques [27].

The previously presented works clearly show that plenty of different approaches exist in the field of SCRM. This is also represented by the large number of publications. For example the search engine Google Scholar provides a little more than two million results for the phrase: supply chain risk management. However, it must be noted that this number contains all types of scholarly literature. By using ScienceDirect, which focuses on academic journals and books, the number of results still exceed 73 000 publications. Some notable examples of the papers found through these searches include the publications of Chopra and Sodhi [29], Christopher and Peck [30], Jüttner, Peck and Christopher [31], Tang [32], Manuj and Mentzer [33] and Tang and Musa [34], among many others. Of course, plenty of other publications could be listed here, but it is also important to analyze the field of risk management outside the strictly defined supply chains, covering the area of logistics networks on a wider scale. This is going to be implemented in the following chapter.

3. RISK MANAGEMENT IN LOGISTICS NETWORKS ON A WIDER SCALE

In order to explore the wider topic, it was also necessary to examine the available literature which is related to the risk management of other types of logistics networks. The main goal of the analysis was to find such publications that contain both a detailed operational risk model involving all elements in the given network, and also a (preferably quantitative) mathematical model on which the risk model is based upon. This required a comprehensive survey which was implemented with the use of the previously mentioned Google Scholar and ScienceDirect academic search engines.

First, the search was implemented with Google Scholar by using the phrase: risk management in logistics networks. This produced a large number (440 000) of results. As previously mentioned, this result contained a wide array of sources, however only the first 990 were shown which were comprised of academic publications. After surveying the listed results, however it became clear that the majority of these concentrate on the supply chains as well, especially on the problem of supply security, which mostly translates into the problem of supplier selection. Of course, some exceptions were found, like for example the work of Goh, Lim and Meng [35], in which there is a greater emphasis on the network model of the supply chain, while the risk factors are also taken into account. However, here the problem is also approached mainly through the analysis of the uncertainties related to supply and demand, and to the various cost elements (for example taxes and exchange rates).

Another example can be the work of Harland, Brenchley and Walker [36], in which a number of different risk sources are taken into account and multiple case studies are also presented. On the other hand, here the described method represents a somewhat more qualitative approach. The search was also repeated in a way that the results were limited to the time period starting from 2013. The final conclusion was the same as in the previous case, with the slight difference that the number of network-oriented publications found this way were somewhat higher than before. Examples for these are the works of Hatefi and Jolai [37], Hearnshaw and Wilson [38], or that of Mari, Lee, Memon, Park and Kim [39], among multiple others. However, it’s still true for these cases as well that the risk is primarily taken into account through the stochasticity of supply and demand, while the reliability of the individual components of the logistics network receives somewhat less attention. On the other hand, the latter search showed that the importance of analyzing the effects of unexpected events on the supply chain has clearly grown lately, which is probably related to the growth of global uncertainty in the recent period.

Finally, the search was repeated with the use of other, similar search phrases, such as the following simpler word combination: risk logistics networks. Again, the result was similar to the previous ones in that the found publications mostly dealt with the problems of supply and demand. Among the exceptions was the work of El-Sayed, Afia and El-Kharbotly [40], in which a stochastic forward-reverse logistics network model was presented in great detail, though the related risks were mainly taken into account from a demand perspective. Another, similarly detailed and network-oriented model was described in the paper of Peng, Snyder, Lim, and Liu [41], but the related risks were again mainly discussed from one aspect, which was the occurrence of disruptions at the facilities involved in the supply chain. As it was mentioned, the search was repeated with other word combinations as well, for example with the following phrases: risk in logistics networks; risk assessment in logistics networks; risks in logistics networks. However, the results in these cases remained similar to the previous ones.

The search was also implemented with the use of ScienceDirect. The phrase which was used first was again the following: risk management in logistics networks. The number of results was 15 935, which was less than the number received through Google Scholar, but as it was mentioned before, this is due to the fact that the latter counts with all types of scholarly literature, while ScienceDirect strictly concentrates on academic journals and books. From the results, it was also clear that the number of related publications has constantly grown in every year since 2009, which coincides with the mentioned similar conclusion from [23].

Besides, it could also be seen that a larger number of the publications found this way are focusing more on concrete problems. Altogether, the search implemented in ScienceDirect provided the same result as the ones realized in Google Scholar, in the sense that a relatively small number of publications deal with the comprehensive, reliability oriented risk management of generally defined logistics networks. One found exception was the publication of Govindan and Chaudhuri [42], in which a detailed risk model based on the DEMATEL (Decision Making Trial and Evaluation Laboratory) approach was presented. It's also important to note that the risk factors in this case were specifically analyzed from the perspective of the 3PL providers. With the described method, the authors thoroughly analyze the interrelationships between the various risks, though the description of the related logistics model receives somewhat less attention.

Another good example is the paper made by Choi, Chiu and Chan [43], in which the authors analyze the different areas of the risk management of logistics systems, while they also propose new research directions. In the publication, both of the areas of operational risk control and logistics service risk analysis are discussed, among other important topics. On the other hand, the aim of this work was to provide a comprehensive picture and propose new research directions, rather than to develop a specific new model. A further good example is the case study presented by Tuncel and Alpan [44], in which the authors introduce an FMECA (failure mode, effects and criticality analysis) based, highly detailed risk model, while they also provide a Petri nets based modelling framework for supply chain networks. In this case, both the risk model and the logistics model are highly detailed and quantitative, though the presented framework has to be uniquely applied for each problem.

The search with ScienceDirect was also repeated with the use of other word combinations, for example with the simpler phrase: risk logistics networks. The search with the latter combination produced 18 503 papers, though these were largely similar to the previously found publications, to the point where a majority of the results were exactly the same. On the other hand, it must be noted that a number of such publications were also found this way which were less strictly connected to the actual topic, but nevertheless provided useful and interesting insights. For example, one of these was the paper written by De Rosa, Gebhard, Hartmann and Wollenweber [45], in which the facility location problem in a sustainable bi-directional logistics network was examined in great detail, in order to provide a robust network model for uncertain operational environments. Another interesting publication was the work of Alem, Clark and Moreno [46], in which the authors presented stochastic network models which can be used for logistics planning in disaster situations. Here, it also has to be mentioned that a significant number of other publications were found which also dealt with the role of logistics in disaster situations. Of course, the search was repeated with the previously utilized various other word combinations as well, but the results remained largely the same.

Table I. summarizes and compares the numerical search results in ScienceDirect for the two standard search phrases: supply chain risk management (from the previous chapter); risk management in logistics networks (from the current chapter). It lists the numerical results since 2009 on a yearly basis.

Table I.
Comparison of the numerical search results in ScienceDirect for the two standard search phrases

Number of search results in ScienceDirect		
Year	**"supply chain risk management"**	**"risk management in logistics networks"**
2017	7,595	2,022
2016	6,414	1,709
2015	5,748	1,431
2014	5,518	1,269
2013	4,552	1,049
2012	4,033	946
2011	3,446	740
2010	2,988	679
2009	2,842	562

On the whole, from the searches implemented in Google Scholar and Science Direct it can be concluded that while the field of supply chain risk management already has an extensive literature, the number of publications that concentrate on the risk management of more generally defined logistics networks is significantly smaller, as it can be seen from Table I. as well. Moreover, a significant portion of the found papers were characterized by the use of qualitative techniques, while the utilization of quantitative methods is somewhat less typical. Besides, it can be observed that the analysis of the reliability of the logistics service providers is very rare, which coincides with the fact that the operational risk factors themselves usually receive less attention. Instead, the risk factors are most often taken into account from the perspectives of supply and demand. These observations and the drawn conclusions will be further elaborated in the following chapter.

4. DRAWING CONCLUSIONS AND PROPOSING A NOVEL APPROACH

The survey of the literature verified the statement that the risk management of logistics networks already has a great significance in the field of logistics, especially in relation to supply chains. On the other hand, it also became clear that the number of those approaches which deal with the risk management of generally defined logistics networks is, at present, still significantly smaller compared to that of the supply chain focused methods. Moreover, the existing approaches usually concentrate on certain sides of the problem. Besides, as a general observation it can be also stated that the majority of the methods put a greater focus on qualitative techniques, while the utilization of quantitative tools is rather preferred in such cases when the problem is more constrained, or when a concrete case study is presented. Altogether, it can be seen that the number of such generally applicable quantitative risk management methods which can be used in a wide variety of logistics networks is still very small, while the use of detailed multi-aspect risk models is also less typical.

Based on the previous, it can be easily concluded that there is a significant potential in the development of new risk management methods for logistics networks. An approach that is based on a generally applicable mathematical model while also contains a detailed and multi-lateral risk model could be especially of great value. Of course, there are multiple available ways for the implementation of such a method. One possible solution could be an architecture in which the risk model would be configurable by the users (usually the manufacturing and service companies in the network) in accordance with the specific problem. The results of the risk model then would be applied in the mathematical model through an indirect way, for example as weights in a goal function. This approach would make it possible to utilize the risk model in various types of networks, while the indirect use of the results would allow the inclusion of an arbitrary number of processes and logistics service providers in the goal function.

The risk model itself can be implemented through multiple ways as well. In this regard, one plausible solution could be the utilization of so called multi criteria decision making methods, as these are specifically applied by the users to derive the order of preference of the examined alternatives – in this case, the risk factors – according to their own judgements. Out of these, one possible candidate could be the AHP (Analytic Hierarchy Process) method, as it is one of the most frequently used such technique. It has numerous uses in the field of logistics as well, especially in the cases of supplier and route selection [47], [48]. Besides, it is also very important to note that there are a lot of examples for using the AHP in relation to supply chain risk management as well, both regarding its standard form [49], [50], [51], [52], [53], [54], [55] and its different variations [56], [57], [58], [59]. *Figure 2* shows a possible way for how to implement a detailed risk model of an arbitrary logistics network as a decision hierarchy, by utilizing the AHP method. The proposed model is built around the mandator company which orders the logistics services in the network (the model counts with eight further risk factors which are compared according to the hierarchy below).

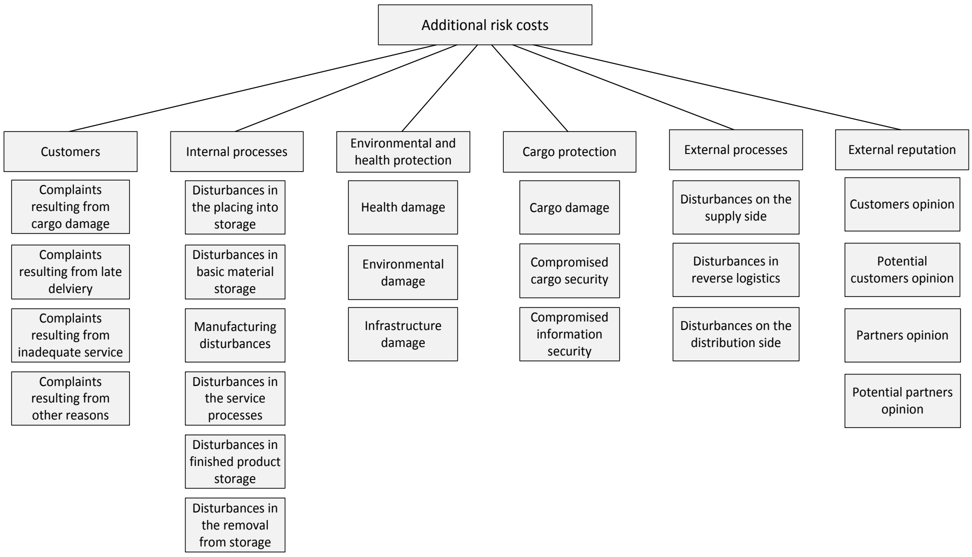

Figure 2. A possible way for implementing a detailed risk model of a logistics network as a decision hierarchy through the use of the AHP, a typical multi criteria decision making method

Of course, besides the AHP, there are plenty of other multi criteria decision making techniques that could be utilized for the creation of the risk model, depending on the way by which the underlying mathematical model of the logistics network is implemented. What is really important from the perspective of the proposed approach, is that the user has to be able to derive the weighted preference order of the risk factors through the application of the elaborated risk model in such a way that makes it possible to utilize the results as weights during the risk-based optimization of the given (but otherwise arbitrary) logistics network. As it became clear from the previous findings, the utilization of such an approach could provide significant benefits, both from a practical and from a research perspective.

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THE DEMAND PLANNER'S SPECIAL ROLE – DEVELOPMENT PROGRAM

JÁNOS MONDOVICS[1]

Abstract: The role and significance of demand planning are increasing in the operation of supply chain, in harmony of the digitalization of production and distribution. Within the corporate operation, this function collects widespread information on both the external and internal processes, interprets them and makes consensus-related decisions about the structure and scale of sales (demand) to be expected in the short term. In this regard, its performance is crucial, primarily, in relation to stocks, the use of capacities, cash flow as well as profitability. Consequently, it is of paramount importance to harmonize the organization surrounding the demand planner and the processes, which is the major goal of the described development program.

***Keywords**: supply chain, forecast, demand planner, forecasting development*

1. INTRODUCTION

Among the supply chain actors, one of the most mysterious functions is the one played by the demand planner. Despite the fact that demand expectations specified by the demand planner are key in terms of stocks and capacity reservations (thus, also in terms of efficiency of corporate operation), the importance and prestige of this role are disproportionate to the responsibility and to the probable consequences. According to skeptical persons (whose way of thinking is moderate), the prestige-related issue generally affects the positions of supply chain.

What is the reason why the evaluation of the role of demand planning (or supply chain management) has become so important and crucial? Key changes made in the industry (Industry 4.0) as well as the spread of the new trade structures (omni-channel) have entailed challenges of faster and more precise performances in supply chain management.

In many cases, it is not clear-cut how the demand and sales planning (forecast) functions are interpreted. Their role(s) played in corporate processes can help to interpret these functions better and more accurately.

2. DEMAND PLANNING

The beginning point of a corporate planning process is the strategic sales planning, in the framework of which primarily the owner's intentions determine the characteristics of the market activity.

The harmonized activity of marketing and sales-related activities are based on this to create a sales strategic forecast.

Demand planning is tightly connected to the strategic sales planning (long-term demand estimates) and to the middle-term sales planning. The goal of demand planning is to meet the pre-targeted service level, due to which the decisions influencing the accuracy of the demand

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estimates along with the specification of safety stocks must be improved on a continuous basis.

In supply chain, two primary sources of uncertainties are known: [1]

– uncertainty of process (realization of production, uncertainty of lead time),
– demand uncertainty.

Figure 1. Major aspects of business planning

We are able to mitigate the uncertainty of demand forecast in practice, on one hand, by safety stocks, on the other hand, by increasing and improving the volume of forecast-related information. Decisions in the entire supply chain are based on the already-approved customer orders, on the planned sales and on estimated demands. Consequently, supply chain performance depends on the quality of demand planning, which requires strong cooperation and joint efforts.

The connection between demand planning and its key means can be understood on *Figure 2* below [2].

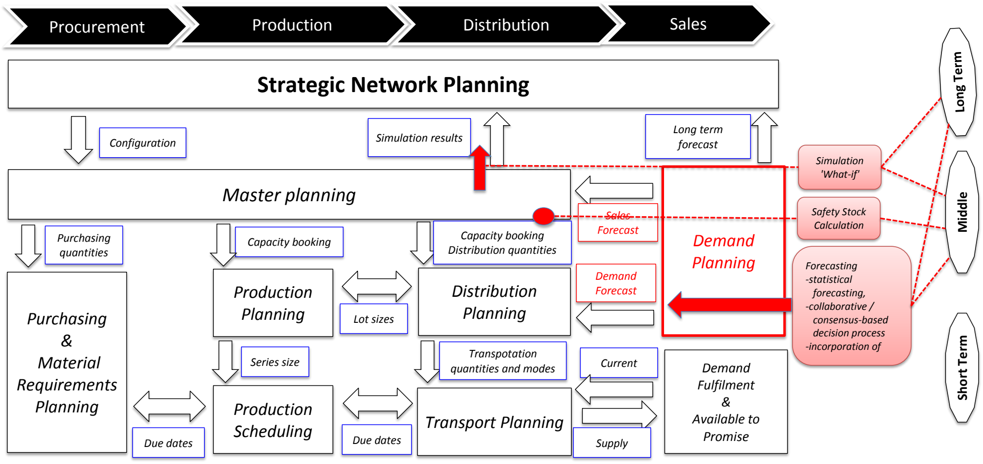


Figure 2. Connection between production planning tasks in supply chain and demand planning

What are the results realized in demand planning and who require these results? The middle-term production major program requires demand forecast per production groups, per geographical sales areas and channels on a weekly basis and, depending on the chain, recommends safety stocks per factory plants and per distribution centers. Demand forecast on a daily basis is required for the short-term stock replacement (for covering demands) per products. The structure of results depends, to a great extent, on the circumstances of applications as well as on the operation-related requirements.

In the course of demand planning, we usually follow the below-described three classic steps:

- The first step of creating forecast is based on statistical analysis, characterized by fine-tuned automatic methods based on extended details and, as a result, we receive the characteristic details of forecast-related time series.
- In the next step, we supplement the time series-related forecast data with the information that we did not take into account in the previous step, such as trade promotions, marketing actions, changes in trade channels, etc.; we can adjust the supplementations to the corresponding matrix of the detailed forecast matrix manually or by the proper software.
- The forecast process is supported by a widespread circle of functional fields in supply chain, such as sales, production, procurement, finance and marketing, with which efficient cooperation – and consensus – based processes must be established, resulting in a consensus-based forecast, which must be applied in every single planning step in the entire supply chain.

3. ROLE OF THE DEMAND PLANNER

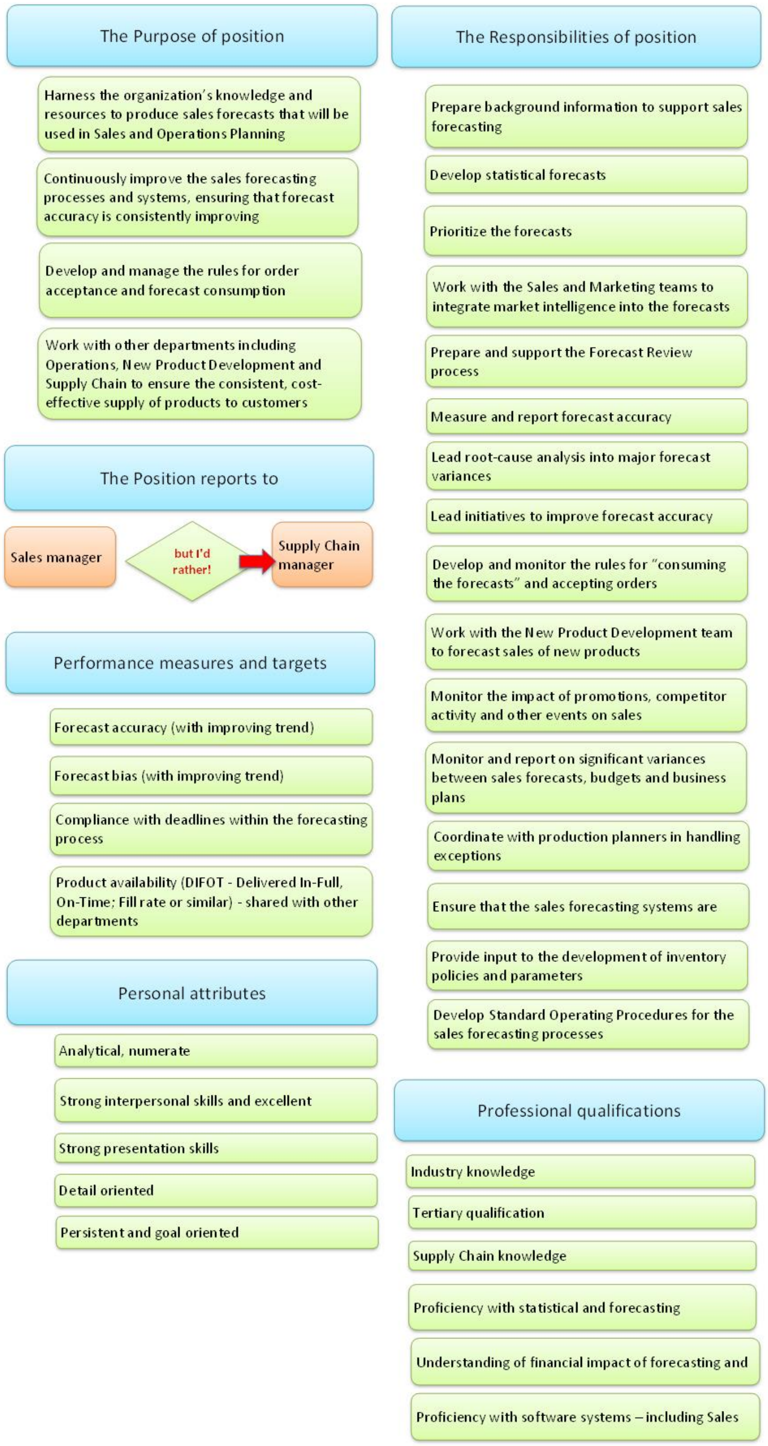
The demand planner's role is special for two reasons, as follows:

1. The demand planner's primary role is demand planning and, as we are aware of it, forecast is always wrong (each forecast is burdened with a statistic error)…
2. This function requires widespread cooperation.

Companies declare that they very much need supply and demand planners who are experts in these fields, however requirements regarding this position are quite various and diverse, as a consequence of which in many cases there are different, highly experienced experts (not junior professionals) with different competencies who are good fit to deliver each task. Among the requirements, the demand for strong math and statistics skills is highly prioritized, but also good communication conducted among and within the organizations is key, just like thorough knowledge gained in the fields of production, logistics, marketing, sales and finance. Who are these savvy professionals and where can they be found?

The core characteristics collected about this function can be viewed on *Figure 3* [3], [4].

Strictly speaking, the forecast is not a "real" planning and decision-making process; it is intended only to serve the purpose that we could project expected events as precisely as possible. Consequently, the thoroughly established systems do not handle the elemental forecast data as determined; they render probability ranges to the elemental forecast data (probability range, instead of a determined number).



The Purpose of position

- Harness the organization's knowledge and resources to produce sales forecasts that will be used in Sales and Operations Planning
- Continuously improve the sales forecasting processes and systems, ensuring that forecast accuracy is consistently improving
- Develop and manage the rules for order acceptance and forecast consumption
- Work with other departments including Operations, New Product Development and Supply Chain to ensure the consistent, cost-effective supply of products to customers

The Position reports to

Sales manager – but I'd rather! → Supply Chain manager

Performance measures and targets

- Forecast accuracy (with improving trend)
- Forecast bias (with improving trend)
- Compliance with deadlines within the forecasting process
- Product availability (DIFOT - Delivered In-Full, On-Time; Fill rate or similar) - shared with other departments

Personal attributes

- Analytical, numerate
- Strong interpersonal skills and excellent
- Strong presentation skills
- Detail oriented
- Persistent and goal oriented

The Responsibilities of position

- Prepare background information to support sales forecasting
- Develop statistical forecasts
- Prioritize the forecasts
- Work with the Sales and Marketing teams to integrate market intelligence into the forecasts
- Prepare and support the Forecast Review process
- Measure and report forecast accuracy
- Lead root-cause analysis into major forecast variances
- Lead initiatives to improve forecast accuracy
- Develop and monitor the rules for "consuming the forecasts" and accepting orders
- Work with the New Product Development team to forecast sales of new products
- Monitor the impact of promotions, competitor activity and other events on sales
- Monitor and report on significant variances between sales forecasts, budgets and business plans
- Coordinate with production planners in handling exceptions
- Ensure that the sales forecasting systems are
- Provide input to the development of inventory policies and parameters
- Develop Standard Operating Procedures for the sales forecasting processes

Professional qualifications

- Industry knowledge
- Tertiary qualification
- Supply Chain knowledge
- Proficiency with statistical and forecasting
- Understanding of financial impact of forecasting and
- Proficiency with software systems – including Sales

Figure 3. Mapping the demand planner's competencies

Therefore, logic along changing demands and probability ranges requires the application of further modules, such as the simulation module and the "what-if" analysis devices in the process. These requirements further demonstrate that the demand planners' IT competences are required.

By drawing the conclusions from the above-written information, in corporate activities, forecast is wrong, in accordance with the tightly managed fields (production, finance), as every single planning step based on demand planning implies, logically, uncertainty. The difference between the forecast-based production and delivery program (their realization) and the actual sales (customer orders) influences the customer service level of the entire supply chain. The customer service level usually does not reach 100%; the safety stock is the proper instrument to improve customer service (depending on the supply chain construction).

As it can be seen, the actual capabilities of an expert suitable for demand planning and its correspondence with the given expert's career path may be quite diverse. There are experts who prefer in-house training, which can be an efficient but, at the same time, challenging solution or, in lack of other solutions, they prefer to hire experts via manpower leasing processes.

A previous survey [5] could provide additional information on the *Tables I–III* below.

Table I.
The demand planner's career path at responding companies

	USA/CAN	**Europe**	**Others**
Stepping stone position on path to other more senior roles in supply chain or finance	52%	53%	68%
Position on which a career path can be built within demand planning/S&OP	31%	33%	24%
Other	17%	15%	8%

Table II.
DFU (demand forecasting unit) number increasing per demand planners

	USA/CAN	**Europe**
Stayed about the same	45%	38%
Risen modestly	35%	43%
Risen sharply	8%	12%
Dropped slightly	12%	7%
Dropped sharply	0%	0%

Table III.
Efficiency of demand planning processes: results.

	USA/CAN	**Europe**	**Others**
Below average	20%	17%	14%
Average	45%	44%	64%
Above average	30%	29%	14%
Excellent	5%	10%	9%

4. THE DEVELOPMENT PROGRAM

The demand planner's operation-related efficiency and the organization's interests are tightly interlinked, however details are influenced by the distorted effects of the balance of power ("who have stronger position and power at a company"), by the deficiencies of collaboration within an organization and, as a consequence, also among organizations. To develop the efficiency of the forecast process (to reinforce the demand planning function), we have developed a complex and modular program consisting of three optional modules *(Figure 4)*.

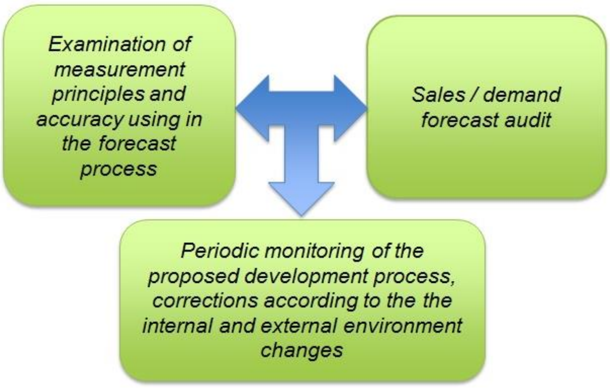


Figure 4. Modularity of the development program

In the first module, the measure principle and accuracy are in the focus. In terms of the measure principles, the forecast process is emphasized, to be more precise, intentions, arisen in the forecast process, as well as the relationship between the planned, the expected demands and the actual performance. Further functions: interpretation of the actual performance; evaluation of calculation variables of forecast error on a specific system; benchmark (accuracy of evaluation forecast, filtering regular error, ABC-XYZ-FMR analysis).

The second module examines the imbedded activity and efficient operation of forecast in corporate processes and makes proposals to more efficient operation. The second module is a multiple structured module. The first viewpoint represents progress see on *Figure 5*.

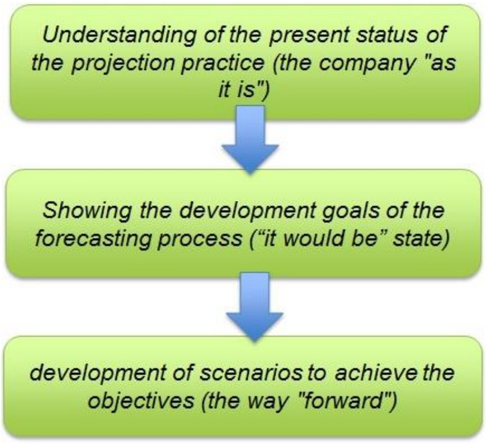


Figure 5. Time horizon of the development program

The second viewpoint is the so-called Development Program of Forecast Efficiency complying with the standard set in accordance with the criteria of *Mentzer, Bienstock, and Kahn (1999)* [6] framework, which has been supplemented in several elements, in accordance with the following sections on *Figure 6*.

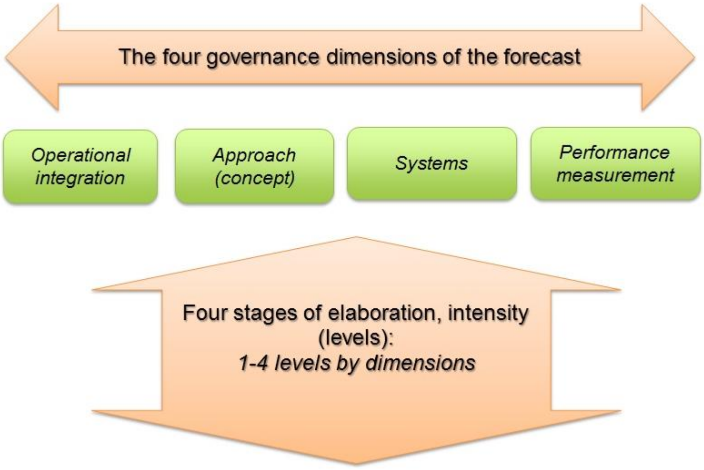


Figure 6. Dimension of the development program

The third module is, briefly, the follow-up; the monitoring of the execution of the jointly defined repair program ("the way forward") and, if required, its correction. This is the phase when the previous module is fine-tuned as well as when flexible reaction to the changes made in the circumstances can be improved.

The development program "draws a map" about the obstacles, which block the corporate's efficient forecast practice and also about the characteristics, and, at the same time, also summarizes the solution's program.

5. CONCLUSION

The development of the industrial digitalization imposes requirements, naturally, on the informational process of the supply chain management (logistics). On one hand, it requires the collection, perception, process and interpretation of information on a wider scale, on the other hand, it requires the more precise determination of demand-related data regarding industrial processes and the continuous search of the operational environment's optimum. In this dual requirement system, demand planning plays a crucial role, as its performance primarily determines the effectiveness of the whole system therefore its role is unambiguously crucial.

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COMPLEXITY ANALYSIS
OF MATERIAL HANDLING DESIGN PROCESSES

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Abstract: Knowledge Based Engineering systems are advanced, effective techniques which can deliver useful solutions for every field of the industry, and it also has relation to the design of material handling processes. One of these methods, the linked KBE/CAD solution, can be applied for the design of different material handling processes. In this paper we describe a calculation method to determine the complexity level of the material handling systems in the aspect of the design process. Complexity level of a design solution has important role in comparing the individual tasks and methods, and it can help to evaluate the application advantages of linked KBE/CAD solutions.

Keywords: *material handling design, KBE systems, parameter analysis, complexity*

1. INTRODUCTION

Application of knowledge based systems in the design of material handling has more than three decades history, but there are no widely used, general, effective methods so far. Knowledge Based Engineering (KBE) systems are advanced, effective techniques which can deliver useful solutions for every field of the industry (e. g. in the automotive industry), and it also has relation to the design of material handling processes. One of these methods uses the linked KBE/CAD concept which can be suitable for different handling processes.

The design of material handling machines and processes uses many handling parameters during the design procedure, which have significant effects to the complexity of tasks. In this paper we give an overview about their most important categories and describe a calculation method to determine the complexity level of the material handling systems in the aspect of the design process. Complexity level of a design solution has important role in comparing the individual tasks and methods, and it can help to evaluate the application advantages of linked KBE/CAD solutions.

2. KNOWLEDGE BASED ENGINEERING IN MATERIAL HANDLING

Knowledge Base Systems (KBS) are computer programs which use Artifical Intelligence (AI) techniques to solve complex problems based on specific experiences of human experts [1]. KBS methods related to material handling use a special database of practical experts which includes their knowledge about material handling equipment and look for results by the comparison of the material flow and handling device parameters [2]. There are many knowledge-based selection methods in the international literature (universal and also device specific), one of the first knowledge-based methods published by *Malmberg et al.* [3] for selection of trucks (PROLOG). After the beginning, there were different attempts to develop

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the simple selection method into optimisation process using special objective functions and analytic algorithms (Hybrid methods, e. g. *Welgama and Gibson* [4]).

Knowledge Based Engineering (KBE) is a technology able to merge the capabilities of conventional Knowledge Base Systems with computer aided analysis and design systems (CAE and CAD systems) [1]. KBE systems enable to insert the result of the knowledge based calculation procedure directly into the design process of machine elements using special software solutions. For the realisation of KBE systems three different solutions were published in the international literature [12]:

- augmented CAD systems with KBE,
- full KBE systems and
- linked KBE/CAD solutions.

Augmented CAD systems with KBE are found in many different CAD environments and have different scopes of operation [5]. Main principle of this concept is that the KBS solution has to be integrated into the CAD environment. Well known commercial products are Knowledge Ware within CATIA and Knowledge Fusion within NX [6]. All approaches together have some common characteristics [7]:

- no full generative modelling and therefore manual adjusting effort,
- no exploitation outside their KBE language and therefore not web-based frameworks,
- lots of editing effort and “unfriendly” scripting languages,
- they only do better donkeywork and are non-reactive to new technologies, etc.

Full KBE systems are object oriented highly advanced generic and super ordinated software programs which apply captured knowledge to design processes by using different visualization tools [8]. The systems must drive the way of design automatically by using various validation rules and should not criticize pre-generated results leading towards engineering process automation. Object oriented KBE (e. g. MOKA [9]) now means inheritance from classes of objects and customization of very much unified models, following the classical tree structure [7]. An investment into a full KBE system is nowadays only seen in automotive and aeronautic sectors [10].

Linked KBE/CAD solutions means a new approach, in which existing KBE and CAD solutions are linked by special software. The basic idea behind this concept lies in using separated system elements for knowledge capture and use as well as geometry representation. In its most basic form the two core elements can be a calculation scheme implemented in a capable software tool and a parametric CAD model. In order to combine them to a full featured application they are bidirectional interconnected to each other via a specialized interface [11].

What KBE means within Material Handling Equipment Design (MHED) is best described in [7]. The first is to specify input parameters in form of rules and constraints classes for KBE in MHED. Some fuzzy criteria such as shape design, leading to customer acceptance or not, and system integration are relevant as well as the “harder” facts concerning manufacturing and costs, which can be formulated within rules much more easy. As every MHE is determined by the demands of throughput (in tons or pieces per hour) it is necessary, to define throughput as the major input parameter [7].

All other classes derive directly therefrom as especially all rules and constraints for design and engineering/sizing. Therein standards have to be considered as well as know-how of employees for i.e. variant management using carry-over-parts to reduce costs and stock for production. Taking all those input together leads to a KBE system of whatever environment, containing a set of rules and constraints settled around the BOM (Bill of Materials) and its underlying product structure. Key feature is the reliable function of the partly automated design, providing the designer with additional information for geometry design. There he gets information about minimal sizes resulting from stress calculations, information about useable space and interface connections all from as less as possible input parameters (throughput, storage capacity, etc.) [7].

Having in mind, that this approach is settled around augmented CAD KBE systems it's not the main objective, to get fully automated design with generative modeling. Also the knowledge reuse is limited, as many of the rules have to be written in CAD scripting language without export functions. Altogether leads to major improvements in the design workflow for MHED and last but not least to better products with less development effort and better cost awareness [7].

To make KBE successful it's necessary, as a key result of literature review, to differ between the various degrees of automation in design work. Design work in material handling is completely different if one has to design a wire-rope drum or if one has to layout a complete storage system [12]. There are certain tasks more or less predestinated for KBE so that with a determination that reflects this degree of automation we can talk about KBx [12], which can be Knowledge Based Engineering (KBE), Knowledge Based System Design (KBSD) and Knowledge Based Layouting (KBL).

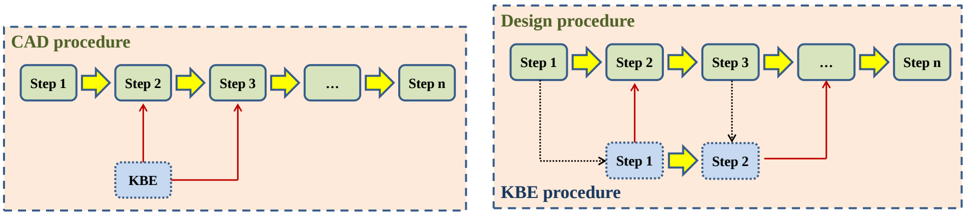
Different KBx has very different scope of use, functions, powering knowledge and application *(Table I)*. The manifestation of automated design in KBx needs a clear database, interconnections and goals for varying applications [12].

Table I.
KBx definitions based on [12]

	KBx Knowledge-based engineering approaches at different detail design levels		
Scope of automated engineering	**KBE** Knowledge-Based Engineering	**KBSD** Knowledge-Based System Design	**KBL** Knowledge-Based Layouting
	Components, parts, machines	*Machines and systems*	*Systems*
Functions	Full automated (detail) design of parts and subassemblies	Full automated master and layout design of assemblies and systems, specifications of machinery	Full automated layouting of systems, specification of systems
Use for	– customizing machinery – tailored products – product families	– dimensioning motors – defining interfaces – CAD top-down design – CAE models	– space requirements – early cost estimation (bidding) – draft bill of material
CAD domain	*detail geometry models*	*reduced geometry for CAE*	*shrink wrap geometry for layout*
Data, information and knowledge sources	– standards, best practice – production facilities – manufacturer data – engineering theory	– standards, best practice – supplier and engine data – engineering and mechanics theory	– standards, best practice – manufacturer data – customer rel. management – logistics theory
	Material flow calculation (throughput, capacity)		

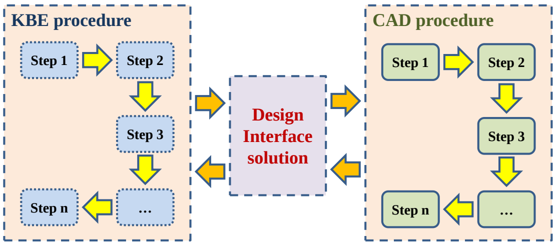
3. STRUCTURE AND OPERATION OF KBE METHODS IN MATERIAL HANDLING

Different KBE solutions have different structures, elements and methods which effect the operation characteristics and the applicability in practice. Structure and relations of KBE at the different methods can be seen in *Figure 1*.



a) Augmented CAD systems with KBE

b) Full KBE systems



c) Linked KBE/CAD solutions

Figure 1. Structures of KBE solutions

In augmented CAD systems with KBE, the role of KBE is minor and the task of it is to determine certain parameters required by the CAD procedure (see *Figure 1/a*). In this case KBE element is linked to a few process elements and the relation exists only in one direction. Full KBE systems contain only one main process, so KBE solutions are integrated deeply to the design procedure (see *Figure 1/b*). It means that the KBE process is parallel to the main design procedure and all the KBE elements have two-direction relations to different design elements. At linked KBE/CAD solutions CAD and KBE procedures are independent each other, only the Design Interface software connects them during certain phases of the design process (see *Figure 1/c*). Main task of the Design Interface is to enable a bidirectional communication for the exchange of parameters, as well as the extraction of visualization and analyzation data (e. g. images, non-parametric geometry and bill of material) of the CAD model [11].

As it can be observed on *Figure 1*, relations among the different elements of the design process have very important role in the applicability of KBE methods. These relations involve mainly the exchange of data required by the given process steps in all of KBE solutions, which data is linked to certain parameters of the designed systems.

In KBE methods for the design of material handling, parameters used in the process appear in different parts of the related process elements. To determine the role and effects of the parameters in the design procedure, we have to describe the main types and characterisations of them.

4. MATERIAL HANDLING PARAMETERS

During the design of material handling we search for solution for one and more material handling tasks. The tasks and also the solutions can be very different depend on many factors, but the realization scheme is the same: the parameters of a task and a solution have to be fitted. The problem is that the parameters of a material handling system are not exactly defined for all the tasks, because they depend on many factors. If we could define, determine and allocate all the required parameters for the design procedure, results of the design process can be better and easily achieved.

There are many parameters, data, characterisation and influencing factors in material handling processes used for different purposes. If we want to make an overview about the most important parameters, we must put them into different categories. Apple [13] defined 4 main categories of influencing parameters for the process analysis of material handling, which were divided into further subcategories (Figure 2):

1. Parameters related to material
2. Parameters related to movement
3. Parameters related to method
4. Parameters related to physical restrictions

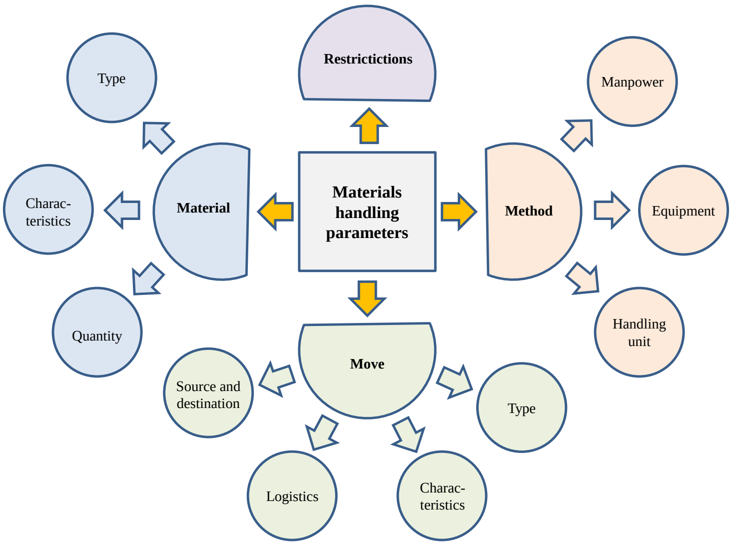


Figure 2. Material handling factors based on [13]

Goods have three different factor-types effecting to the handling process: type, characteristics and quantity (see *Figure 2*). Type can be unit, bulk, liquid or gas [13]. Characteristics of the material have many aspects from geometric data to the handling specifications, depend on the type and behaviour of the goods. It is hard to give short overview about them, but the international literature presents many details in different approaches (see [14]). Quantity of the material basically determines the handling process and can be in different dimensions (kg, m^3, pieces, etc.). Calculations of the material handling process requires material flow data in generally, especially the material flow intensity (in kg/s, pcs/h, etc. – see [15]).

Movement parameters of a handling process can also be grouped into four main categories: source and destination, logistics, characteristics and type [13]. Sources, destinations (manufacturing objects, stores, etc.) and their relations determine the transport routes and the scope of the moving. Logistics defines the level and range of the material handling activities (internal, external, etc.). Characteristics of the movement involve all moving parameters (speed, distance, frequency, etc.) and environment conditions. Type of the movement can be transporting, conveying, transferring, loading, etc. Material handling method can be manual solution (handling at workplaces, in stores, etc.) or use of handling equipment (manually controlled or automated, continuous or discontinuous) and depends on the unit used for handling (pieces, palettes, boxes, containers, etc.) [13]. Parameters belonging to the movement method involve all the machine and unit parameters. Restrictions contain all parameters which limit for the application of possible solutions and influence the design process [13]. They can be physical restrictions, operation limits, applying problems, etc.

Different parameters have different roles in the design of the material handling, so to analyse their effects another approach has to be applied. The main concept of the design process is that we have to determine the parameters of the applied solution based on the parameters of the handling task. In the aspect of this design concept, parameters can be categorized into three groups [2] *(Figure 3)*:

1. Parameters of the handling task
2. Parameters of the applied solution
3. Influencing parameters

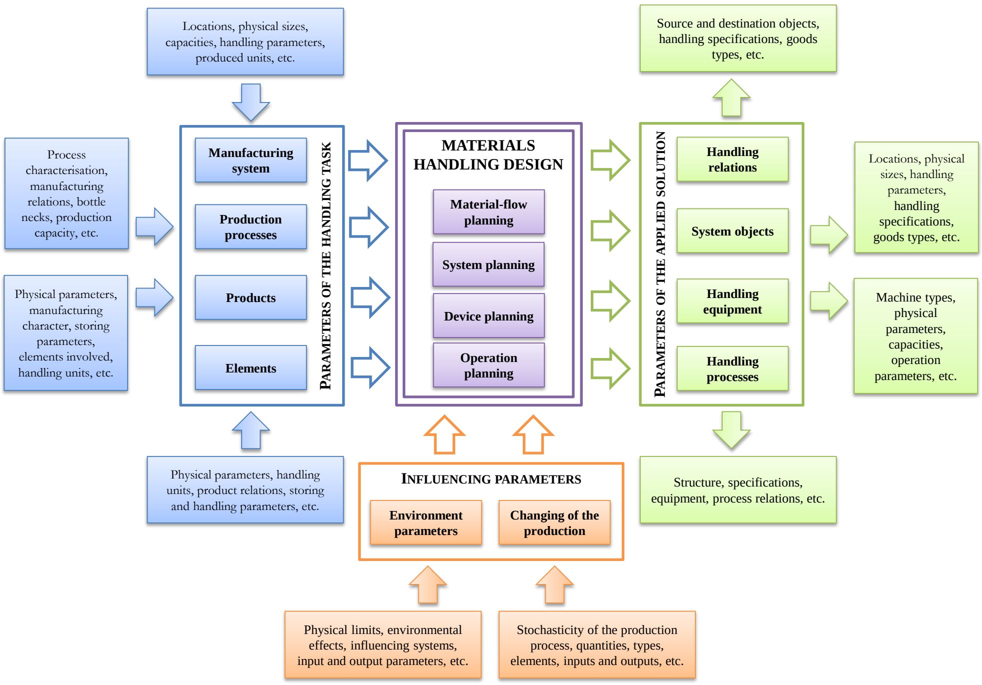


Figure 3. Role of the parameters in the design process of material handling

Parameters of the handling tasks are calculated based on the related manufacturing or service process steps and can be applied for description of the material handling process. Parameters of the applied solution define the specifications of the material handling equipment and limit its applicability. Influencing parameters are usually not depending on the material handling process, but they have many effects on it.

Different handling processes require different design methods, so the actual set of parameters used in a design process is also different. It means that all the design tasks and methods use a determined set of parameters. Of course, this is evident for the individual planning solutions (e. g. location planning, device-planning), but it can be problematic for complex, large-scale design processes.

This is especially true for KBE systems, where two or more really different design processes have to be suited. If we can exactly separate and determine the required parameters for the individual design elements, the process can be much more effective and the complexity level can also be reduced.

5. EFFECTS OF HANDLING PARAMETERS TO THE COMPLEXITY OF THE DESIGN

Design of material handling systems is not a simple task, there are many methods for the selection of the different equipment and to determine the details of the material flow tasks, but none of them can give a generally applicable, effective solution. The most problematic point is the large deviation between the different devices and the material handling tasks [16].

The design solution can be task-based or system-based approaching. The task-based approach uses individual material handling tasks *(Figure 4)* during the design process, system-based approaching analyses the whole system and the relations of the system elements [17] and tries to find similarities with other systems. The task-based approaching is much more published in the international literature (e. g. [18]), its important advantages are the use of real material flow parameters and better mathematic description.

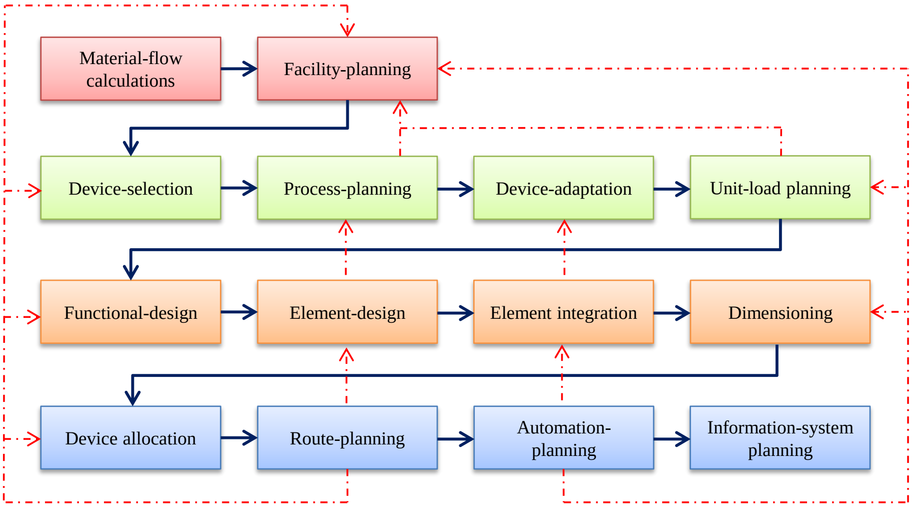


Figure 4. Design elements used in task-based approaching

Design tasks used in task-based approaching can be solved as an integrated process, as an individual task or as a combined solution.

If all the tasks must be solved during the design, then we must use an integrated design process [19]. In this case, all the tasks can be actualized individually; but every task effects each other, so an iterative method is required. The iteration number is determined by the complexity of the material handling tasks (it can be huge in complex cases). As the result of the design procedure we have got an equipment set and an allocation variation, which are near the optimal handling solution.

If the design tasks can be solved individually, the design process will be easier, because many proved specific method can be used [2], but a problem is appearing: the result will only be optimal in the aspect of the given task. Combined solutions mix the specifications of the integrated and the individual design, but they can be very different [11]. This concept involves at least two design tasks, which have to be realized together.

Complexity of material handling design processes depends on different factors, but the most important are:

- number of the involved design tasks,
- number of the parameters taken into account,
- number of the system elements,
- complexity of the relations among the system elements, etc.

All influencing factors have special effect to the design process, however the applied design tasks, the number and relations of the system elements are determined by the given handling process, so it cannot be influenced generally. Of course, many solutions are existing to optimize the design processes in the aspect of the above-mentioned factors [e. g. 20], but it is out of the scope of our paper.

Our research idea is to reduce the complexity of the design processes depending on the parameter-structure and -relations. To reach this objective we must analyse the influencing parameters of the handling process. If we can determine relations and direct influencing effects among the different parameters, we can reduce the complexity level of the material handling design processes.

5.1. Analysis of the parameter structure of handling processes

Complexity is one of the most important description parameters of large, complex systems, which can help to understand and solve their design and operation tasks. It is especially true for technical systems, where complexity has significant role [21].

Individual design tasks use given set of handling parameters, which is suited to the task and its specifications. Based on the number of the parameters in the set, we can define a complexity level for the design process. This complexity level cannot describe the characterisation of the design process, because the other influencing factors are also required, however it can give information about the complexity of the task, which can help to compare the individual tasks and methods.

For example, if we must use two design methods to solve a given handling task, and we know how many parameters are applied by the individual methods during the solution, we can calculate the complexity level of them. If both methods give the same results, the better will be what uses the simpler process. The lower the complexity level of a design method, the simpler will be the way which can be applied for the calculations.

Complexity level of a design task *(C_{task})* can be calculated based on the number of the parameters which can be taken during the process into consideration and the quantity of the system elements involved in the task:

$$C_{task} = \frac{\sum_{i=1}^{N} n_i^{f_i} \cdot p_i}{R_{st}} \tag{1}$$

where

N – number of parameter groups related to the material handling system,

p_i – number of parameters in parameter group *i*,

n_i – number of system elements for which the parameters of parameter group *i* are valid,

f_i – object coefficient related to the number of system elements for which the parameters of parameter group *i* are valid,

R_{st} – reference number containing the total number of the parameters related to the material handling system.

Object coefficients *(f_i)* used in (1) are depending on the number of the objects, elements, parts, etc. of the system and take the effects of the numerosity into consideration (the higher the number of the elements, the smaller the effects of one element to the complexity will be). Reference number *(R_{st})* defines a base to compare the individual tasks of a given system, its value is the total number of the parameters in the analysed system.

Based on *Figure 3*, we can describe all parameters which influence the material handling system. Naturally, the number of the parameter groups and its elements depend on the given system, we listed the most important parameters in *Table II*, which also presents the minimal value of the reference number (R_{st}) for this case.

If we actualize equation (1) for a given task and for the whole integrated design process, we can compare the complexity levels of them.

In case of integrated design, we can take all the parameters into consideration, so the complexity of the production process *(C_P)*, the influencing factors *(C_I)* and the handling process *(C_H)* can be calculated as

$$C_P = n_{mo}^{f_{mo}} \cdot p_{mp} + p_{pp} + n_p^{f_p} \cdot p_p + n_e^{f_e} \cdot p_e \tag{2}$$

$$C_I = p_{ep} + p_{cp} \tag{3}$$

$$C_H = n_{hr}^{f_{hr}} \cdot p_{hr} + n_{hs}^{f_{hs}} \cdot p_{hs} + n_{he}^{f_{he}} \cdot p_{he} + p_{hp} \tag{4}$$

$$C_{task} = C_M + C_I + C_H \tag{5}$$

where

f_{mo} – object coefficients for the manufacturing objects,

f_p – object coefficients for the products,

f_e – object coefficients for the elements,

f_{hr} – object coefficients for the handling relations,

f_{hs} – object coefficients for the handling system objects,

f_{he} – object coefficients for the handling equipment,

other parameters are involved in *Table II*.

Table II.
Parameters influence the material handling systems

PARAMETER TYPES	**Number of system elements**		**Number of parameters**	
	Type	***Variable***	***Variable***	***Value***
A) Production parameters			**p_M**	**→68+**
1. Manufacturing system	manufacturing objects	**n_{mo}**	**p_{mo}**	**→19+**
Object locations (x, y, z)				3
Object sizes (D, W, H)				3
Object capacities (pieces, speed, performance, etc.)				3+
Handling parameters (clutching method, storing possibility, etc.)				2+
Handled unit parameters (sizes, weights, shape, etc.)				5+
Produced units (types, quantities, variations, etc.)				3+
2. Production process parameters			**p_{pp}**	**→16**
Process (type, times, breaks, relations)				4
Manufacturing relations (relations, sources, destinations, lines, units)				5
Production capacities (available, used and remained capacities, needs)				4
Bottle necks (minimum performance, differences, free capacities)				3
3. Product	products	**n_p**	**p_p**	**→18+**
Physical parameters (size, weight, shape)				5
Manufacturing characterisation (type, series, etc.)				2+
Storing parameters (units, racks, handling method)				3
Elements involved (types, quantities, relations)				3
Handling units (sizes, weight, pcs involved)				5
4. Elements	elements	**n_e**	**p_e**	**→15+**
Physical parameters (sizes, weight, shape)				5
Handling units (sizes, weight, pcs involved)				5
Storing parameters (units, racks, handling method)				3
Handling parameters (clutching method, orientation, etc.)				2+
B) Influencing parameters			**p_I**	**→23+**
1. Environment parameters			**p_{ep}**	**→11+**
Physical limits (location restrictions and prescriptions, etc.)				3+
Environmental effects (temperature, humidity, wind, dust, chemicals, etc.)				5+
Influencing systems (transports, services, relations)				3
2. Changing of the production			**p_{cp}**	**→12+**
Stochasticity of the processes (orders, supply, scheduling, etc.)				3+

Quantities (series, loading units, transport units, etc.)				3+
Types (variations, minor differences, etc.)				2+
Elements (availability, distribution, etc.)				2+
Raw materials (availability, distribution, etc.)				2+
C) Handling parameters			p_H	**→58+**
1. Handling relations	handling relations	n_{hr}	p_{hr}	**→17+**
Source objects (types, locations)			4	
Destination objects (types, locations)			4	
Handling specifications (clutching, orientation, movement, etc.)			3+	
Handled goods (types, units, sizes, quantities)			6	
2. System objects	system objects	n_{hs}	p_{hs}	**→13+**
Object locations (x, y, z)			3	
Object area (D, W, H)			3	
Handling specifications (clutching method, storing possibility, etc.)			2+	
Handled units (sizes, weights, shape, etc.)			5+	
3. Handling equipment	machines	n_{he}	p_{he}	**→16+**
Machine types (variations, specifications, etc.)			6+	
Physical parameters (sizes, weights, etc.)			4+	
Capacities (loading, transport, speed, etc.)			3+	
Operation parameters (characteristics, driving specifications, etc.)			3+	
4. Handling processes			p_{hp}	**→12+**
Processes (types, times, breaks, etc.)			4+	
Specifications (tasks, time-limits, joining, etc.)			3+	
Equipment (types, applicability limits, additional elements, etc.)			3+	
Process relations (types, joining possibilities, etc.)			2+	
Reference number for the design process:			R_{st}	**Σ 149**

Based on (2), (3), (4) and *Table II*, the complexity level of an integrated design process can be calculated easily. As an example, we defined a system with given number of manufacturing objects, products, elements, handling relations, handling objects and machines, and applied a given value for the object coefficients (f_i). Results of the complexity calculation with the predefined data can be followed in *Table III*.

Of course, the applied values influence the complexity level of the system, however if we use the same values for all the design processes, we can compare the complexities of them. If we want to use this concept for a real material handling system, we need to determine the parameters and the numbers of the objects, products, elements, handling relations, handling objects and machines in the system exactly, and we also have to use a predefined value for the object coefficients (f_i).

Table III.
Calculation of the complexity level of an integrated design process

	A) Production parameters				B) Influencing parameters		C) Handling parameters			
	1. Manufacturing system	***2. Production process***	***3. Product***	***4. Elements***	***1. Environment parameters***	***2. Changing of the production***	***1. Handling relations***	***2. System objects***	***3. Handling equipment***	***4. Handling processes***
Number of parameters	p_{mp}	p_{pp}	p_p	p_e	p_{ep}	p_{cp}	p_{hr}	p_{hs}	p_{he}	p_{hp}
	19	16	18	15	11	12	17	13	16	12
Number of elements	n_{mo}	–	n_p	n_e	–	–	n_{hr}	n_{hs}	n_{he}	–
	10	–	5	30	–	–	10	12	5	–
Coefficients	f_{mo}	–	f_p	f_e	–	–	f_{hr}	f_{hs}	f_{he}	–
	0.5	–	0.5	0.5	–	–	0.5	0.5	0.5	–
Total values:	**60**	**16**	**40**	**82**	**11**	**12**	**54**	**45**	**36**	**12**
	Σ 198				**Σ 23**		**Σ 147**			
Complexity level:	**368 / 149 = 2.47**									

To evaluate the complexity level of the full integrated design process, we have to compare it with smaller tasks, however they can be very different. It is out of the scope of our paper to present the complexity of all design tasks, so we will show the details of one task (unit-load planning).

Table IV contains the calculation of the complexity level for unit-load planning, where we can see that fewer parameter groups and parameters have to be taken into consideration. In the aspect of the numbers of the objects, products, elements, handling relations, handling objects and machines in the system, the same values are applied than during the integrated design process. It is also true for the object coefficients *(f_i)* and the reference number *(R_{st})*.

As it can be seen in *Table III* and *IV*, in the example system, the complexity level of the single unit-load planning (1.59) is significantly lower than the value of the integrated design (2.47). In this concept, the minimal value of the complexity level theoretically can be $C_{task} = 1$, which means that we use only one system element in every parameter groups. Comparing the complexity levels of the integrated design solution and the unit-load planning, we can evaluate the work related to the processes in the different cases.

An important question is how we can calculate the complexity level of the design process, if we have to use more than one design task in one process together.

Table IV.
Calculation of the complexity level of unit-load planning

	A) Production parameters				B) Influencing parameters		C) Handling parameters			
	1. Manufacturing system	***2. Production process***	***3. Product***	***4. Elements***	***1. Environment parameters***	***2. Changing of the production***	***1. Handling relations***	***2. System objects***	***3. Handling equipment***	***4. Handling processes***
Number of parameters	p_{mp}	p_{pp}	p_p	p_e	p_{ep}	p_{cp}	p_{hr}	p_{hs}	p_{he}	p_{hp}
	–	–	15	15	3	–	17	10	10	7
Number of elements	n_{mo}	–	n_p	n_e	–	–	n_{hr}	n_{hs}	n_{he}	–
	–	–	5	30	–	–	10	12	5	–
Coefficients	f_{mo}	–	f_p	f_e	–	–	f_{hr}	f_{hs}	f_{he}	–
	–	–	0.5	0.5	–	–	0.5	0.5	0.5	–
Total values:	**0**	**0**	**34**	**82**	**3**	**0**	**54**	**35**	**22**	**7**
	Σ 116				**Σ 3**		**Σ 118**			
Complexity level:	**237 / 149 = 1.59**									

5.2. Complexity level of KBE methods in material handling

In case of using more than one design tasks together, we can take the complexity levels of the individual tasks into consideration (e. g. apply the higher complexity level of them), however it does not give suitable result, because the common solution usually requires iterative techniques. The best is if we recalculate the complexity of the tasks taking all the parameters and other influencing factors of every task into account. The resulted complexity level will be higher than in the individual cases *(Table V)*. In special cases, if the parameters used in the tasks are the same, the complexity levels of the tasks and the common solution will be also the same. As an example we described the parameters of unit-load planning and device planning in *Table V*. to show the effect of the common solution.

Application of augmented and full KBE systems needs similar calculations process to determine the complexity level, however the linked KBE solutions gives different results.

In linked KBE systems, the KBE and CAD methods are principally separated during the process, so the complexity level of them has to be calculated in a different way.

In most of the cases, the KBE and CAD methods meet only some special parameters (in our example these are the physical and handling parameters of the unit-load device), which do not increase the complexity of the process. If the linking interface uses more, additional parameters for the planning, these will increase the complexity level of the design procedure. As in our example, the linking interface does not use other parameters, the complexity level of the solution will be the same as the higher value of the two involved design tasks *(Figure 5)*.

Table V.
Effect of the common task to the number of the parameters

PARAMETER TYPES	**Parameters taken into account during the design process**		
	Unit-load planning	*Device planning*	*Unit-load + device planning*
A) Production parameters	**→ 30**	**→ 0**	**→ 30**
1. Manufacturing system	**0**	**0**	**0**
2. Production process	**0**	**0**	**0**
3. Product	**15**	**0**	**15**
4. Elements	**15**	**0**	**15**
B) Influencing parameters	**→ 3**	**→ 0**	**→ 3**
1. Environment parameters	**3**	**0**	**3**
2. Changing of the production	**0**	**0**	**0**
C) Handling parameters	**→ 44**	**→ 53**	**→ 53**
1. Handling relations	**17**	**17**	**17**
2. System objects	**10**	**13**	**13**
3. Handling equipment	**10**	**16**	**16**
4. Handling processes	**7**	**7**	**7**
Total:	**77**	**53**	**86**

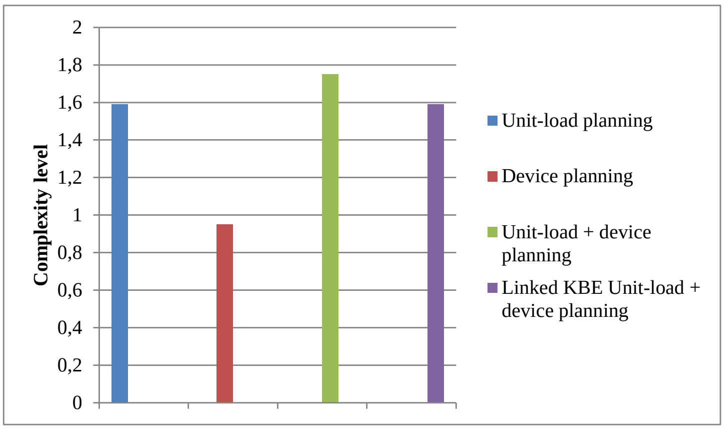


Figure 5. Complexity levels of the analysed cases

One of the most important consequences of our analysis is that the complexity level of a linked KBE solution is in generally lower than the integrated application of two different material handling design tasks. Of course, we need additional work to make an interface program for the linked KBE solution, but it will save time and work for the user during the application process.

Of course, the main objectives of this complexity analysis were to define and explain a method which is suitable to compare the different material handling design methods. In this paper we described this method in generally and apply it for a given example to demonstrate the applicability and analyse the effects to a linked KBE solution.

The general analysis and the description of the details of this concept is out of the scope of this paper, but this will be the next step of our research. We hope that the new concept will be applicable for the evaluation of many practical design methods in the field of material handling (e. g. device selection, facility planning).

6. SUMMARY

Knowledge Based Engineering systems are advanced, effective techniques, which can deliver useful solutions for every field of the industry. There are different variations of KBE systems for the design of material handling machines and processes, one of these methods use the linked KBE/CAD concept which suitable for different handling processes.

Material handling parameters have significant role in the design processes, so in this paper we gave an overview about their most important categories and described a calculation method to determine the complexity level of the material handling systems.

To show the applicability of the complexity level in the design process we presented some examples, which can help to compare the complexity of the different design tasks and processes. As a result, we state that the use of linked KBE/CAD systems can reduce the complexity level significantly which is a great advantage in the aspect of the design process.

Next step of our research can be a more detailed analysis of the design tasks related to the material handling processes, which can help to select new task relations to involve the linked KBE concept.

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IMPORTANT STEPS IN PURCHASING PROCESS

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Abstract: The last century brought significant changes to the automotive industry and represents a significant economic and technological force in the life of countries connected to the industry. The automobile manufacturing fabricates its products primarily through mass production however, the segment producing exclusive vehicles executes manufacture type production many times due to the small-scale volume. These effects highly impact the international supply chains.

Keywords: *globalization, logistics, supply chain, automotive, supplier relationship*

1. INTRODUCTION

Today, international competition and the appreciation of the life cycle of products shortened greatly affect the operation of enterprises, the fundamental objective is to meet the customer demands a higher standard of quality and a lower price [1]. In response to the requirements, downsizing and concentrating on their core business of the company. The manufacturing companies are looking for suppliers who can supply good quality raw material and components at low cost [2].

Purchasing up to the seventies had a largely administrative role in corporate operations [3], but later recognized the function of reducing corporate costs. Nowadays, procurement activity has become strategically important as it has a serious impact on the company's performance and therefore plays an important role in corporate strategy.

2. THE CONCEPT OF PURCHASING

Purchasing is the process which is usually handled by the corporate logistics, it can be divided into three parts: purchasing, production and sales logistics. The purchasing logistics stands at the beginning of the processes of material flow: it provides those input inventories, which are required to complete the production (or the service, in a broader interpretation).

The average industrial company spends 55–85% of its income on these, so the most economical and secure execution of this task is vital. Purchasing can be listed into two main groups [4]:

- raw material/manufacturer purchasing: so-called direct purchasing,
- purchasing of services/additional materials: indirect.

The task of the purchasing agent includes tracking down, qualifying, competing and assessment of the suppliers. The bigger the ratio of the purchasing costs, the bigger importance the purchasing gains in the company, and thus it is placed at a higher organi-

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zational structure. But no matter where the decision is made, it is very important that it is conceived integrally with the other organizational units, it should not create a separate function from other logistical units [5].

The goal of purchasing in the strategy: to acquire products and services of adequate quality in the adequate quantity, at the proper time, from the proper supplier, at the proper price. These are known as the „five adequate" factors.

Centralized purchasing: a central body purchases the necessary raw materials for all the units, it carries out organizing the whole task of purchasing.

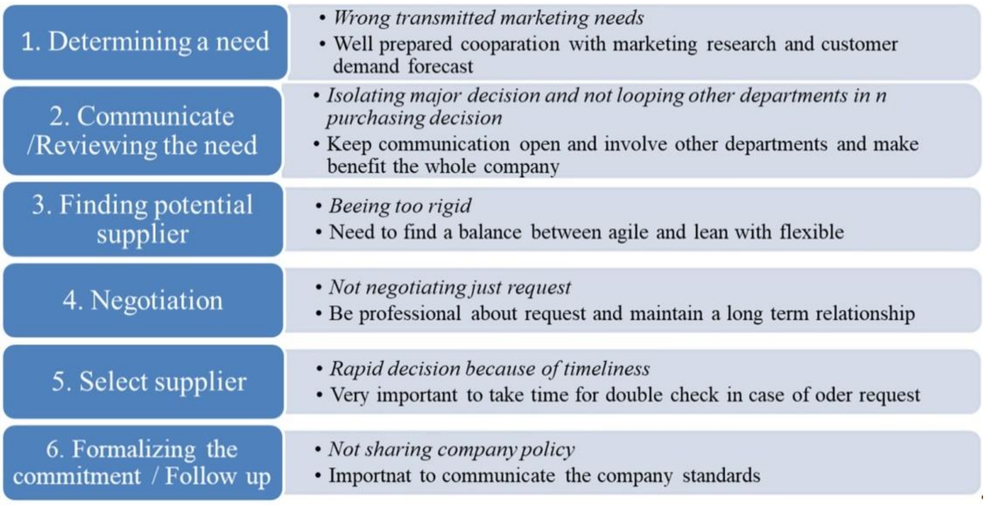
- Advantage: it is cheaper being a single unit.
- Disadvantage: it is less able to meet individual requirements.

Decentralized purchasing: each individual unit purchases the materials needed for them individually.

- Advantage: almost complete fulfilment of individual needs.
- Disadvantage: they fail to get a price discount, which comes by ordering large quantities.

3. STRUCTURING STEPS OF PURCHASING PROCESS AND POSSIBLE MISTAKES IN PROCUREMENT CYCLE

The effectiveness of company's purchasing ability depends on the procurement system. An inefficient system leads to a whole host of purchasing problems. These mistakes aren't all that difficult to correct.



1. Determining a need	• *Wrong transmitted marketing needs* • Well prepared cooparation with marketing research and customer demand forecast
2. Communicate /Reviewing the need	• *Isolating major decision and not looping other departments in n purchasing decision* • Keep communication open and involve other departments and make benefit the whole company
3. Finding potential supplier	• *Beeing too rigid* • Need to find a balance between agile and lean with flexible
4. Negotiation	• *Not negotiating just request* • Be professional about request and maintain a long term relationship
5. Select supplier	• *Rapid decision because of timeliness* • Very important to take time for double check in case of oder request
6. Formalizing the commitment / Follow up	• *Not sharing company policy* • Importnat to communicate the company standards

Figure 1. Purchasing process steps and possible mistakes in procurement cycle

The most common procurement mistakes have fairly simple solutions. Many problems in the purchasing department can be solved with technology. Others are a result of human error or organizational shortcomings. Even when using purchase order software, there are still some tasks that need a human touch. It's easy for purchasing managers to get into the habit of doing things a certain way and overlook areas where the purchasing department can improve. Here are some of the common procurement mistakes.

4. RANKING OF SUPPLIERS, PREPARATION OF THE SUPPLIER DECISION

One of the most important steps of companies is to be able to create a structured image using the already existent and potential supply networks. With the help of a supplier model we can create a reviewable supplier ranking. But which are the aspects worth considering? Firstly, the structuring of suppliers is happening based on groups of materials. At factory level, the local professional purchasers are responsible for the operative tasks [6].

The middle and long term strategically decisions are the tasks of the so-called commodity team leader, who sits at the top of the organizational structure. It is of basic relevance that a price offer can be issued only to those suppliers, who are already present among the company's suppliers. Only in specially justified cases (a technical specialist) can such a supplier be chosen who is not among this circle of suppliers. For the sake of reviewability, the company places its partners *(Figure 2.)* into a supplier pyramid according to the following structure.

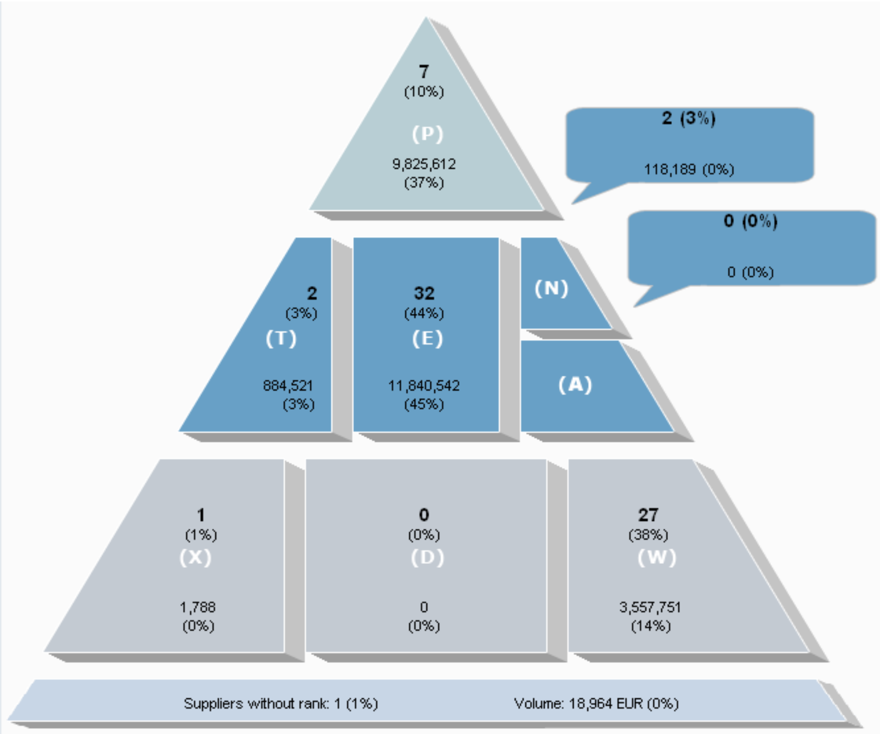


Figure 2. Supplier pyramid

As a main rule, it can be said that it is needed to acquire information well before the price offer request about the current state of the suppliers classified into the given component group. Regarding each component group, the individual so-called commodity manager is finalizing the classification based on the discussions with the professional purchasers of various factories. A supplier, who held a position with priority status can also lose its position if one of the factory units' negative experience can duly confirm this [7].

This database is realized in the so-called supplier pyramid, which has the following meaning.

- P: "preferred supplier" as the name suggests, the preferred suppliers of the given component group are part of this circle, in the event of a favourable price offer they can get new business without any reservation. This ranking can be obtained based on the performance, reliability, quality and other favourable characteristics proven through long years.
- T: "technical specialist" technical specialists, partners who are specialized on a given production technology's special field. Only in justified case (the competitors are not technically able to produce the given product) do they get business.
- E: "essential" everyday partners: most suppliers belong to this group, among whom there is stiff competition going on. They are reliable partners, but from strategically reasons further ramp-up increase is not justified (it is at the limits of its capacity, its price level is not exceptionally favourable, etc.).
- N: "new" suppliers: they do not get new business. In case of supplying serial components undisturbed for one year, they will step up to rank „E".
- A: "acquired": a theoretical group, until this very day none of the suppliers ended up in this category.
- X: "to be actively eliminated": the group of those suppliers, with whom the business has to be laid off as soon as possible, the production equipment has to be transferred to a different supplier. There is a deliberate strategic decision lying in the background, based on which the company does not desire to continue further cooperation.
- D: "determined by customer": the group which is required by the customers. When THE OES buyer obliges that the spare parts shipped to him can contain exclusively the units produced by the sub-supplier required by him.
- W: "without new business": supplier that cannot get new business for some reason (problem with capacity). This ranking can be declassified after e. g. expansion of capacity. Experience shows that partners listed into this ranking will receive after longer-shorter time „essential" qualification once again, so we are talking only about a temporary state.

5. PARTICIPANTS IN THE PURCHASING PROCESS

Supplier decisions belong exclusively to the purchasing's competency. All the other departments can, of course, give suggestions, can share their experience (e. g. if there are continuous quality issues with one of the suppliers) which are weighted by the purchasing and it makes the decision on signing the contract afterwards. With this knowledge, although in a small measure, all departments can give a suggestion to the supplier decision, but the final decision belongs to the purchasing circle's responsibility.

The examples below show what kind of risks and mistakes can emerge in connection with the given supplier. The partner departments can influence/"take part" in the supplier evaluation and selection decision based on their experience and opinions the following way.

- Development engineering: Based on previous experience, serious difficulties arose with company XY in the field of communication, originating from the use of non-

compatible CAD systems. The desired corrections/alterations were not completed according to the drawings.
- Logistics department: supplier XY is unable to complete the requests. A reason for that may be a problem with the capacity or possibly a breakage of machinery, non-appropriate production planning or inventory strategy.
- Quality department: supplier XY beside the continuous manufacturing is sending or shipping faulty, non-suitable to fit parts, thus increasing the culling (rejection) costs of reworking.

6. IDEAL PURCHASING PROCESS IN CASE OF A NEW PART

The company is aware of its needs and it can describe these accurately. After finding the suitable supplier, which is not easy, the negotiating phase starts [8]. Here the conditions have to be clarified regarding price, shipping, timeframe and the methods. It is important for the company to know within which timeframes the shipping is needed so that its shelves would not be empty for the customers. By the clarification of conditions and signing the contract, the order has to be traced, so that everything would be adequate. In case of lack of satisfaction, it is worth for the company to look for a new supplier, since neither qualitatively, nor quantitatively, nor because of the lack of time it is not fortunate for the successfulness of the company to make the mistakes.

- The demand comes from the development department: there would be a need for part XY. For this the drawing is necessary, respectively the transmission of various information such as materials used and manufacturing technology.
- Parallel, the Quality department communicates their expectations with the purchasing.
- Based on the surveys of Marketing/Information available to sales department the quantity index numbers of the parts creating the object of the price offer are decided, as well as the expected lifetime of the project.
- Sending the price offer request to the suppliers with the knowledge of the technical and quality requirements. Applying different price request formulae based on part groups. It is easy to admit that there are different technical questions referring to e. g. a machined steel axis, or an injection moulded cogwheel. Corresponding to this, different offer requesting formulae are needed. The offer requests must contain in detail all those points, which influence the interval of the product development e. g. machinery setup time, raw material purchasing time, production line building time.
- Possible fine tuning of drawing requirements, based on the suppliers' recommendations after a technical conciliatory discussion. In this phase, such a significant drawing modification might occur which can influence the price of the product.
- Evaluating of the incoming price offer. During the evaluation, the unit price of the given part has to be considered, respectively the cost of the preparations needed for manufacturing of the spare part, the lead time (equipment cost, production line modification cost), the geographical location of the supplier, its quality indicator number produced to date, the lead time of the parts.
- During the price discussions and technical conciliation, the overview of the calculations of the part, respectively the equipment needed for manufacturing the part, mechanical installations are happening. There is decision aiding target software

at hand for conducting accurate, extensive analysis of these calculations of all influencing factors (where, in which country would be the part manufactured, with what kind and how old installations, from what kind of materials, involving how many direct/indirect workers, etc.).

- Choosing the supplier: in spite of the company management's efforts, it is an exceptionally bureaucratic process, during which the purchaser responsible for the given project will validate his prior decision with all his superiors. On some kind of level, it is justified since they are preparing a framework contract possibly running for multiple years, with multiple hundred thousand series quantity.
- Contracting: during contracting, the price and the lead time are already known, which is the interval ranging from receiving the contract until its fulfilment. The contract contains the details of the client and the selling party. It contains accurate description of the given part, fixes the price, deadlines respectively the ownership of the equipment needed to manufacture the part. It important to highlight that this is a preliminary agreement. In case of mass production, the logistics department will summon the parts, the completion/payment will be made based on these quantities.
- Performing the preparations needed for manufacturing: depending on the manufacturing technology, it is a period covering more months, during which the equipment, assembly line is completed which is needed to manufacture the part (mould injection tool, high pressure aluminium casting mould)
- Manufacturing the sample piece and sending it to the buyer. The buyer's 10-approval happens the following way. After the completion of manufacturing the equipment or manufacturing installation, there is a need for a so-called equipment trial. During the analysis of the parts by installing them into the product, there might be a need for further modifications/corrections. As soon as the part gains its final state, the supplier will hand in a so-called official first sample to the quality department, which will undergo measurements, tests and installation trials. If the part is approvable, then mass production can start.
- Serial shipping: mass production: the parts are summoned/ordered during the mass production by the logistics department, the purchasing is only providing a supporting function. Depending on the evolution of the price of raw materials, it can renegotiate the prices, if needed, it can secure new/alternative purchasing sources.

7. SUMMARY

The companies cannot afford to choose contractors based only on their prices. It must always be a purpose that the material to be purchased have the appropriate quality, arrive in (at a) right time, in appropriate quantity from adequate sources, at correct prices [9]. To realize it, the purchasing strategy must be well planned, which is easier with the Kraljic matrix calculating the importance of the goods to be purchased and the complexity of reaching the contractors. Finally, risk analysis must be made in every case in order to face the least possible problems and unsatisfied partner relations.

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