Innovation’s influence on transport systems competitiveness in view of the market uncertainty

1. Introduction

Transport evolution is realized in two opposed directions - developments and degradations, which proceed with various speeds. And, with respect to the following transport generations any evolutionary transformation serve as the precondition for its further perfection. Evolutionary transport’s technodynamics is asymmetrical in time owing to irreversibility of innovation. Consequently, in any condition and at any moment functioning of transport is necessary to consider not only as process of performance of production targets, but also as innovative transformation process of its construction. Interaction of functioning principles and evolution principles is reflected, in particular, through relationship of categories “transport’s moving ability” and “transport’s innovativeness”. At the same time, introduced innovations depend on speed of vehicles degradation and can influence rate of transport’s development in the double aspect:
- directly through gradual accumulation of quantitative conversions of vehicles construction.
- indirectly through cardinal principles transformations of vehicles functioning.

There is a set of potentially possible trajectories for transport’s development. Only one of them is realized in practice. The mechanisms forming this trajectory, it is possible to divide into three conditional groups (See Fig.1):

A. Mechanisms of local conversions. For the first time have been considered in paper Ellul, J. (1964). Further were investigated in papers Misa, T. J. (1994), MacKenzie, D. (1996). The analysis of these researches has allowed to draw the conclusion: that mechanisms of local conversions are formed under influence of the changes: knowledge-base, users (decision-makers) preference, market’s potential, technology needs. This mechanisms initiatives:
- the creat changes which are not touching principles of vehicles’ functioning;
- stable dynamics of TS’s (Transport System) development;
- transfer of resources for unconditional preservation of TS’s structure.

B. Mechanisms of systems transformations. For the first time have been offered in paper Saettler, P. (1968). Further were investigated in papers Perez, C. (1983), Stockdill, S.H & Morehouse, D.L. (1992), Tenner E. (1996) etc. Their analysis has allowed to draw the following conclusion: that structural transformations are inevitable at enough accumulation of local conversions. In result the TS passes into the radical phase directed to qualitative transformations of:
- principles of vehicles’ functioning;
- trajectory of TS’s development;
- components basis and organizational structures of TS.

C. Mechanisms of innovation’s diffusion. For the first time have been considered in paper Rogers, E. M. (1962). Further were investigated in papers Davies, S. (1979), Freeman, C. 

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1 From Latin “innovare” – to make something news.
2 Trajectory – the solution to a dynamical system in forward and backward time passing through a specified initial condition.
Perez, C. (1988), Andergassen, R. & Nardini F. (2002) etc. The analysis of these researches has allowed to draw the conclusion about inevitability of innovative waves’ formation and their diffusions in the ISTS (Innovation’s Segment of the Transport Market).

It is necessary to mention out the papers Baumol, W.J. (2002), Ambroziak T. (2002) and Semenov, I.N. (2003), finishing a general characteristic of transport development’ mechanisms. The analysis of these researches has allowed to distinguish the following exogenous and endogenous components of TS’s evolution factors.
- stimulating its progressive development;
- regressive, predestining disintegration its fossilized structures;
- focused on support of transport’s steady functioning.

2. Innovation diffusion. Historical background

The historical analysis of forecast methods’ for innovations’ diffusion allows to distinguish: The first group. Unites the methods basing on the statement about priority of “imitating behaviour”. The first investigations in this direction have been executed Mansfield E. (1968). The method him offered is based on the following assumption. The probability of the positive decision about the innovation’s application depends on firms’ number which have already made such decision (early adopters). Introduction of such hypothesis predetermines S-shaped character of the trajectory describing innovations’ diffusion in time. In turn Sahal D. (1981) has offered the following hypothesis: speed of innovations’ diffusion is proportional not only to already achieved level, but also break between current level and potentially possible level of innovations’ use. His model’s reproduction of novelty diffusion look like:

$$\frac{d N}{d t} = r N (K - N)$$

where $N$ - parameter determining the achieved level of TI’s diffusion;
$K$ – parameter characterizing potentially achievable level of the ISTM saturation;
$r$ – coefficient of proportionality;
\( t \) – time parameter.

The equation solution (1) looks like function:

\[
N = \frac{K}{1 + a e^{-b t}},
\]

where \( b = r \times K \)

- \( a \) – coefficient, which characterizes entry conditions of TI’s diffusion;
- \( b \) - parameter characterizing the increase of TI’s applications number;
- \( \gamma \) - coefficient of proportionality.

**The second group.** Unites the methods basing on the statement about the priority of exogenous and endogenous factors, which form process of innovation’s diffusion. Such approach has been offered Bass F. (1969). His model look like:

\[
N_t = N_{t-1} + p \left( m - N_{t-1} \right) + q \frac{N_{t-1}}{m} \left( m - N_{t-1} \right)
\]

where \( m \) – parameter describing potential capacity of the ISTM.

- \( p \) – coefficient describing influence exogenous factors on introductions number’s (e.g., probability that the clients, which not wish to use an innovation, will change the opinion under influence of advertising, etc.);
- \( q \) - coefficient describing influence endogenous factors on introductions number’s (e.g., probability that the clients, which not wish to use an innovation, will change the opinion under influence of the expanded information on it).

**The third group.** It is based on methods of statistical information’s processing. It is applied by regulative bodies, including EC which has introduced notion DII\(^3\), comprises the following indicators (weight in brackets)\(^4\):

- Population with tertiary education \((k_1=1.0)\) / lifelong learning \((k_2=1.0)\);
- SMEs innovation co-operation \((k_3=0.25\) for manufacturing & \(k_4=0.25\) for services);
- Innovation expenditures \((k_5=0.25\) for manufacturing and \(k_6=0.25\) for services);
- Sales of new-to-firm products \((k_7=0.5\) for manufacturing and \(k_8=0.5\) for services);
- Internet access/ use \((k_9=1.0)\) / ICT expenditures \((k_{10}=1.0)\);
- Volatility rates \((k_{11}=0.5\) for manufacturing and \(k_{12}=0.5\) for services).

The considered approaches do not take into account influence of the information on innovation diffusion’s tempo. The author offers the approach to modelling this process taking into account a knowledge’s degree of its actors.


3.1. Information risk’s measures

Diffusion success of an innovation depends on knowledge’s degree of its actors. The information uncertainty level of actors is higher, than they are further from the novelty source (effect of deep uncertainty). Generally this level is determined by properties of "value", "obsolescense" and "dissipation" of the information. We shall consider these properties by the example of decision-maker’s knowledge.

\(^3\) Diffusion Innovation Index.

\(^4\) CORDIS focus: European Innovation Scoreboard 2003, EC 2003, p.21.
**Information value.**

Value of the information is basic parameter forming at decision-makers, the knowledge level of an introduced innovation. It is characterized by utility, from the point of view of his knowledge; availability; timeliness; completeness and reliability. Let be primary:

- information uncertainty of the decision-makers was measured $U_i^\nu$.
- the risk of decision-making about the TI’s introduction amounted $R(U_i^\nu)$.

Let, that at the expiration of the period $\Delta t$, the decision-maker has received the additional ITI $I_\Delta$, which has lowered his uncertainty up to $U_i^\nu$. Then:

- information uncertainty of the decision-maker will decrease up to $[U_i^\nu - U_\Delta]$ level.
- the risk’s reduction of decision-making about the TI’s introduction is equal:

$$ R(U_i^\nu) - R(U_i^\nu - U_\Delta) = \Delta R_i^\nu. $$

Consequently, the quantity $\Delta R_i^\nu$ reflects the approximation’s degree of the decision-maker to the virtuous decision about refusal / introduction of TI.

**Information’s obsolescence.** All volume of the ITI accessible to the decision-maker, consists of quickly obsolescent and slowly obsolescent data. For example, quickly obsolescent data it is the information about number of the firms introducing novelty or the economic benefits achieved after introduction of an innovation, etc. Slowly obsolescent data it is the ITI e.g. (technical, functional, etc. characteristics of the TI). Let the decision-maker is in a situation “A”, which is characterized by on-line receipt of the data about conditions of ISTM and its ITI uncertainty is equal $U_i^o$. Risk of vicious decision is equal $R(I_i^o)$ in this situation. The situation “B” is possible too, in which the decision-maker does not receive the new ITI during time $\Delta t$, and his uncertainty increases on $U_\Delta$. Then, risk’s increase of the vicious decision is equal:

$$ R(U_i^o + U_\Delta) - R(U_i^o) = \Delta R_i^o. $$

Hence, quantity $\Delta R_i^o$, is the risk’s measure of obsolescent ITI. If the decision-maker receives the information:

- *in regular - determined mode*, i.e. $R(U_i) \to 0$, that he has constantly actual ITI, and process of its obsolescence does not influence probability of vicious decisions;
- *in irregular - stochastic mode*, i.e. $R(U_i) >> R(U_i^o)$, that he has no constantly actual ITI, it negatively influences rationality of the decision-making.

**Information’s dissipation.**

As a rule, the ITI is dissipated on the time period, and it nonliner created by set interacting actors. It is necessary to take into account the fact of interaction of such sources also, when the ITI in process of verification passes from one source in another. At the same time:

- if the larger level of the information verity, the longer its life-cycle;
- if the larger scale of information’s dissipation, the larger probability of existence of false information sources.

Let the decision-maker is in a situation “A”, which is characterized by on-line receipt of the firsthand information from the limited number of sources. Decision-maker’s information uncertainty is equal $U_i^\nu$. Risk of vicious decision is equal $R(U_i^\nu)$ in this situation. The situation “B” is possible too, in which the decision-maker receives the ITI from numerous

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5 ITI - Information about Transport’s Innovation.
sources, including secondary, tertiary, etc. The part from these sources is not free from a false ITI. Then, risk’s increase of the vicious decision about refusal / introduction of TI amounts:

\[
R_i^d \left( U_i^d + \sum_{n=1}^{m} U_n^d \right) - R(U_i^d) = \Delta R_i^d,
\]

where \( m \) – sources’ set probably containing a false ITI. 
\( n \) – secondary sources’ set containing unverifiable ITI.

Hence, quantity \( \Delta R_i^d \) is the risk’s measure of dissipated information.

The information’s properties marked above demand the new approach to modelling diffusion of TI. And, the diffusion’s demension of novelty must be described in terms of nonlinear techno-dynamics. This assertion is connected to variability of ISTM’s conditions, on account of preference systems’ instability (See Table 1).

<table>
<thead>
<tr>
<th>N</th>
<th>Decision-makers / Actors</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Haulier / Forwarder / Carrier</td>
<td>Sustainable access / Competitiveness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexibility / Compatibility / Reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OPEX / CAPEX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traffic volumes / Speeds etc.</td>
</tr>
<tr>
<td></td>
<td>End Users / Consumers / Travelers / Clients</td>
<td>Quality / Security / Safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accessibility / Mobility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transit comfort / Time / Price</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequency of departures etc.</td>
</tr>
<tr>
<td>2</td>
<td>Investors / Implementors</td>
<td>Firm Image / Brand Image / Leadership</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Investment feature / Location advantages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P I / NPV / PBP / IRR / PIMS etc.</td>
</tr>
<tr>
<td>3</td>
<td>Community / Public organizations / Socially active members</td>
<td>Environment pollution / Global warming</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congestion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased leisure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quality - public services, security, etc.</td>
</tr>
<tr>
<td>4</td>
<td>Authority / Policy-makers / Regulators</td>
<td>Economic growth / Taxation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase employment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Efficient use energy/Resources</td>
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<tr>
<td></td>
<td></td>
<td>Social and human development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>National safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Development of infrastructure etc.</td>
</tr>
</tbody>
</table>

Table 1. Preference systems in the transport market

For the modelling of the TI’s diffusion techno-dynamics is recommended:
- to form input information data base;
- to create and investigate investors’ profile;
- to make profile of innovation’s diffusion in local, regional and global dimensions.

3.2. Diffusion dimensions

Generally the TI can be distributed in three dimensions differing both dimensionality, and speed of diffusion. Both these of parameter depend on the information volumes accessible to innovative process’ actors. Let’s distinguish the current \((SK)\) and relative \((sk)\) volumes of the ITI. The parameter \((sk)\) is calculated as the ratio of the current ITI volume to final ITI volume \((SK_f)\), necessary for actors of the innovative process and sufficient by him for virtuous decision making about refusal / introduction of the TI in moment \((t_f)\). Then:
\[
sk = \frac{SK}{SK_f} = \begin{cases} 
    sk \Rightarrow & \text{for all } SK < SK_f \quad npu \quad t_i \neq t_f \\
    1 \Rightarrow & \text{for } SK = SK_f \quad npu \quad t_i = t_f 
\end{cases}
\] (7)

<table>
<thead>
<tr>
<th>Location</th>
<th>Infrastructure project</th>
<th>Investment (billions USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telecommunications</td>
<td></td>
<td>249.1</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td>192.8</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
<td>106.1</td>
</tr>
<tr>
<td>Water and sanitation</td>
<td></td>
<td>31.4</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Asia and Pacific</td>
<td></td>
<td>168.6</td>
</tr>
<tr>
<td>Europe and Central Asia</td>
<td></td>
<td>62.5</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td></td>
<td>285.6</td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td></td>
<td>15.3</td>
</tr>
<tr>
<td>South Asia</td>
<td></td>
<td>33.5</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td></td>
<td>13.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>579.3</td>
</tr>
</tbody>
</table>

Table 2. Investment in infrastructure projects by sector and region, 1990 to 1999


**Company dimension.** Diffusion is sporadic. Probability of the capture the headlines:
- is defined by the input information of actors \((0 \leq sk < 1)\) and is characterized by volatility;
- has properties of the breakthrough.
If the ITI is limited to promotional materials, for example, i.e. practically is absent \((sk \approx 0)\), decision making about refusal / introduction of the TI in this dimension is maximally complicated \((k_{cm} = \max \Rightarrow t_{dec} = \max;)\).

**Regional dimension.** Diffusion is confined to region’s zone. Probability of the capture the headlines is:
- determined by information volume about functional and economic efficiency of the novelty which increase from a level \(sk > 0\) up to a level \(sk \Rightarrow 1.0\);
- characterized by investment susceptibility (see Table 2).

**Global dimension.** Hasn’t spatial restrictions. Probability of the capture the headlines is:
- determined by conjuncture on the world market;
- depended on preference of all actors (see Table 1).

The analysis of modelling results for the TI’s diffusion on each of the listed phase allows to draw the conclusion about existence of connection between levels of novelty and complexity of their introduction. Formalization of this relationship look like:

\[
sk = \begin{cases} 
    0 \Rightarrow & k_{cm} = \max \\
    sk_i \Rightarrow & \min < k_{cm} < \max \\
    1 \Rightarrow & k_{cm} = \min
\end{cases}
\] (8)

where \(sk_i\) - relative volume of the ITI;
\(k_{cm}\) - decision complexity’s level about refusal / introduction of the TI.

The variants’ variety of the innovative decisions differing in volumes of the accessible ITI, spawns the problem of investment behaviour.
4. Investors configurations profiles

Let's consider possible investment strategy of NGA\(^6\). Suppose \(S(t)\) is the total volume of NGA investments on an analyzed ISTM.

![Investors ranking of location advantages](image)

**Fig.3. Investors ranking of location advantages.**

\(w_{97} = 0.135\) \(w_{05} = 0.125\)

\(w_{97} = 0.135\) \(w_{05} = 0.105\)

\(w_{97} = 0.173\) \(w_{05} = 0.154\)

\(w_{97} = 0.189\) \(w_{05} = 0.145\)

\(w_{97} = 0.227\) \(w_{05} = 0.179\)

\(w_{97} = 0.000\) \(w_{05} = 0.167\)

\(w_{97} = 0.189\) \(w_{05} = 0.125\)

\(w_{97} = 0.227\) \(w_{05} = 0.167\)

\(w_{97} = 0.000\) \(w_{05} = 0.167\)

**Source:** Author’s elaboration of a *International Investment: Towards the Year 2001*, United Nations, 1997 Sales No. GV.E.97.05

The set of investor’s strategy distinguish three heterogeneous alternatives:
- change of offered spectrum of the innovative projects (creates the phenomenon of novelty centers);
- expansion of traditional offered volume of expanding projects (creates the phenomenon of extension centers);
- placing of free assets into saving projects, e.g. banks, securities etc. (creates the phenomenon of lagging centers).

Then \(S(t)\) can be used for formation of three investment behaviour:
\[
S(t) = S_r(R,t) + S_x(E,t) + S_k(K,t)
\]

where \(R\) – parameter defining business expense of the TI projects;
\(E\) – parameter defining business expense of the projects expanding production activity;
\(K\) – parameter defining the free assets placing in saving projects;
\(S_r(R,t), S_x(E,t) i S_k(K,t)\) – net investments allocated into alternative projects.

The separate financial flows can be represented in the form:
\[
\begin{align*}
S_r(R,t) &= S_0(R,t) + a_r \cdot \Delta S(t) \\
S_x(E,t) &= S_0(E,t) + b_x \cdot \Delta S(t) \\
S_k(K,t) &= S_0(K,t) + c_k \cdot \Delta S(t)
\end{align*}
\]

where \(a_r, b_x, c_k\) – compensation factors;

\(^6\) Non-Government Agent.
$\Delta S(t)$ - oscillatory shift in volumes of investment flows.

It is necessary to take into account that the application of oscillatory shift with sign (+) increase in volume of financial flow, and with sign (-) - its reduction.

The structure’s indicator of investment projects ISTM has three particular forms. For example, for innovative projects:

$$SI(t) = SI_0 \pm a_c \cdot w(t) = \frac{S(I,R,t) - S(I,E,t) - S(I,K,t)}{S(t)}$$

where $SI_0 = \frac{S_0(I,R,t) - S_0(I,E,t) - S_0(I,K,t)}{S(t)}$, and $w(t) = \frac{\Delta S(t)}{S(t)}$.

The considered approach can be used for modelling configurations and other actors of innovative process, including authority, community and users of ISTM.

Conclusions

On the basis of the aforesaid it is possible to draw the following conclusions:

1. Evolution of transport is under the influence of innovative, regressive and stabilization factors, operating in various directions.
2. Under certain conditions their various combinations take the form of local/system transformations’ mechanisms forming a trajectory of transport development.
3. The knowledge degree of innovative process actors predetermines TI diffusion’s dynamics.
4. At modelling innovative process is recommended to distinguish its local, regional and global phases. Dominant condition of innovative process’ success is its rational investment. One of its parameters is the index of investors configuration.

Reference

9. Innovative actions for regional development are implement by The European Commission within the Framework of the ERDF Regulation N 20863/93, Official Journal N L193 of 31.07.1993