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FLEXIBILITY IN HIGHWAY NOISE MANAGEMENT

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Abstract. The problem of noise management was taken as a key element of our life comfort. An adequate noise mitigation plan must be elaborated and implemented for a number of potential noise sources. The general idea of FLENOMA2 (FLExibility NOise MAnagement for A2 POZNAN BY-PASS) advisory system was based on flexibility options situated on different management levels. In the recent years, two significant noise sources have been established in Poznan agglomeration: POZNAN BY-PASS A2 as a part of A2 highway (BERLIN–MOSCOW) and the NATO aircraft base in Krzesiny. Both are situated in the urban area of Poznan city. Special emphasis will be placed on flexibility noise mitigation options as an example of operational decision-aid. However, finding a compromise solution based on diffused (using the Internet) information about the noise map (will be present in the near future) is the second goal of this system.

Keywords: noise management, highway, hierarchic approach, flexibility management.

1. Introduction

Transportation noise has emerged as an exceptionally troublesome factor lowering our life comfort. It can be characterized as:

- a general phenomenon as in the end of the 20th century, 65% of the population of the European Common Market countries was exposed to the unhealthy levels of transportation noise and its growth during the last decade of the 20th century, was estimated at ca 10% (Suter 1991).
- an environmental factor influencing man in an exceptionally complex way (not only affecting the sense of hearing because its influence can be assessed considering medical and sociological aspects) (Kalibatas and Turskis 2008).
- a natural effect of progress connected with even more powerful and mobile sources of noise generating sounds at an ever changing level etc.

One of the central paradoxes in noise control results from the inhabitants' requirement for fast access to transport (motorways, fast railway transport, e.g. TGV etc.) accompanied by a simultaneous demand of a high level of life comfort in the same place (obviously connected with keeping noise at an appropriately low level) (Bazaras 2006; Bazaras *et al.* 2008; Akgüngör and Demirel 2008). The effects of noise include direct and cumulated negative influence on human health with a simultaneous downgrading of life comfort in work, habitation and learning environments.

Various studies (Willich *et al.* 2006) have confirmed the influence of noise on cardiac infarction risk in the places such as work and residence (Baltrėnas *et al.* 2007a; Zavadskas *et al.* 2007a, b). It is an example (a segment of the problem) since the known influence is exceptionally complex and manifests itself by the following exemplifying effects (Goines and Hagler 2007): loss of hearing, sleep disorders, reduced effectiveness of work, impairment of teaching (and learning) effects, absenteeism, increased consumption of drugs (pharmacophilia), accidents at work, mood depression etc.

From the point of view of decision making, an important detail is that only a part of the effects of the above discussed influence can be assessed taking into account their economic aspect (reduced effectiveness of work, absenteeism, accidents at work) while the majority of them range beyond the limits of economy and in many ways are difficult to be observed (e.g. interpersonal conflicts). Certainly, we can indicate the numerous possibilities of noise reduction consisting (Baltrėnas *et al.* 2007b; Kaklauskas and Zavadskas 2007), e.g. of:

- changes in production process (industrial noise),
- increasing requirements concerning noise emission (e.g. silent means of transport),
- cutting down production in the noxious branches of industry (as shown, e.g. in Poland),

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- changes in transport techniques, e.g. from road transport to railway or waterway transport,
- differentiation of fees for using transport infrastructure according to noise emission levels (e.g. at airports),
- activities aimed at reducing the environmental impact of motorways (e.g. the construction of motorways in excavations or tunnels, the construction of acoustic baffles etc.),
- providing a public opinion with comprehensive information concerning the current and expected noise levels at specific locations (e.g. in the form of acoustic maps) etc.

To design FLENOMA2, the hybrid advisory system and the last two activities were principally implemented. It facilitates operational decision making on the one hand and reaching a consensus/compromise between the groups of participants in the process of decision-making aimed at reducing inconveniences resulting from the environmental impact of noise - on the other. Despite the remedial measures mentioned above, the problem of noise impact on humans needs to be solved, particularly in view of growing influence (e.g. due to the development of transport for many reasons like business, recreation etc.).

2. Describing the Problem

When analyzing the problem of prevalent attitudes to noise and its impact on live environment, one cannot escape from the feeling of 'déjà vu' which is an analogy to activities connected with other factors of harmful effect on human existence (e.g. lead, mercury or asbestos). It is probably hard to believe that even in the 21st century, people ignore the influence of asbestos on human health (the popularity of asbestos-containing roofing materials in Poland, particularly in village areas, is a serious problem). The location of the NATO air base within the city of Poznan in the beginning of the 21st century is another example of disregard for the basic principles of noise control as the key assumption of the latter is to make proper location decisions since the efficiency of the existing noise suppression methods in case of a city of about 600 000 inhabitants (an assessment of the entire agglomeration exceeds 1 million) is extremely low. Such approach brings to mind analogies to the present problem of smoking tobacco (including a very profitable branch of related industry) where an unwise decision made by a single person exposes the health (and frequently life as well) of other people who must live and/or work in a poisoned environment.

The main problem, therefore, is to make everyone aware of the harmful effects of noise and to seek solutions to the problem by reaching a compromise negotiated between the representatives of the various groups of interest. In this case, the most important point, without any doubt, will be to find a legal framework by implementing appropriate regulations (to maintain our analogy to the problem of smokers: non-smokers' life comfort was greatly enhanced by instituting smoking bans in public utility buildings, by reducing advertisements for tobacco products and by banning smoking in airplanes). We should understand, however, that any implemented permissible noise level values concern, first of all, the average levels, and they can be hardly considered as sufficient to guarantee life comfort in specific situations (e.g. work, learning, recreation, convalescence, medical treatment etc.) (Viteikienė and Zavadskas 2007). Thus, the problem is complex and not least due to the typical requirement for regional development, i.e. efficient transport (Despiney and Paslawski 2001). Fig. 1 illustrates the problem of working out a compromise in decision-making concerning the impact of motorway noise if we take into account the interests of two groups including those who want to protect the environment and those who incline towards the economic development of the region. Similar diagrams based on network thinking could be built for related problems, e.g. seeking a compromise in decisions concerning the construction of acoustic baffles (advocates – peace lovers, opponents – local entrepreneurs, in view of reduced access to the road and less opportunities for advertisement).

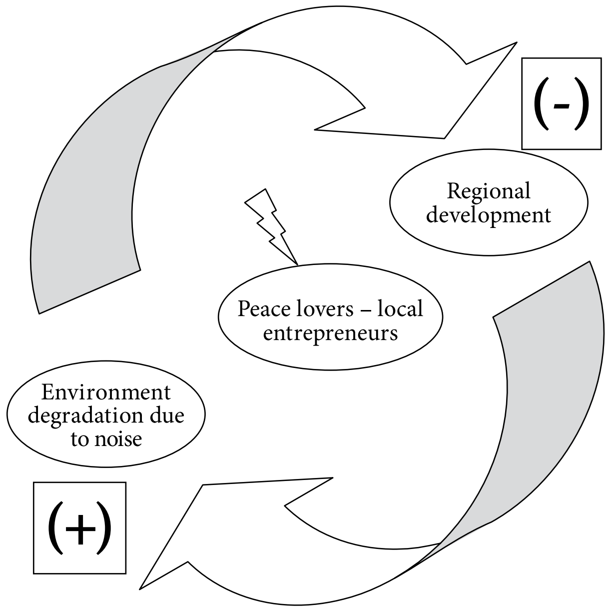

Fig. 1. A conflicting problem of regional development and environment degradation

Taking into account all the problems described above, introducing two Directives of the European Parliament and the Council, i.e. 2002/49/EC and 2003/4/EC should be favourably accepted since they guarantee the access of the public opinion to environmental data and participation in discussions on remedial activities in the field. In light of a complicated character of the relations between the possibility of keeping noise at an appropriate level and other factors (e.g. regional development), it seems advantageous to support the decision making process by applying an advisory system. Attention should be paid to the need for working out a compromise in several issues through a dialogue between the representatives of various social/influence groups (e.g. entrepreneurs who are responsible for noise emission in connection with their business activities and/or interested in access to their residences including proximity to a motorway, airport, fast railway line, sea port etc.) on the one hand and pensioners interested in a maximum reduction of noise and up to the acts of the intentional damaging of road surface in order to reduce the comfort of its users (reduction of the number of users) decreasing speed on the other (Personal info – observation concerning traffic problems in Steszew region (route Trzebaw–Dymaczewo – intentional damaging of road surface in order to reduce the number of users and their speed – obtained in 15 April 2007)).

It is necessary to emphasize the unique importance of a specific character of management in the construction industry (e.g. due to the complex chains of quality relations – a high complexity of a product, its immobility or an extremely long life cycle), particularly in road construction, resulting first of all, from (Banaitienė *et al.* 2008; Zavadskas *et al.* 2008a):

- the requirements of improving the facility while using it, due to changes in operating conditions on the one hand and the need to gain profit (e.g. toll motorways built under BOT system = build, operate, transfer) on the other;
- a huge impact on human life and health related to the danger of road accidents as well as the problem of noise discussed in this paper along with accompanying other types of pollution (air, water) (Komarov and Fedotov 2006), for example vibrations (Kliukas *et al.* 2008a, b);
- the existence of an appropriately dense traffic network as the basic condition for regional development;
- a complicated situation of controlling the conditions of use (e.g. it is not a secret that the permissible capacity of vehicles in Poland is regularly exceeding and considerable violations, particularly in cargo transport, can be noticed).

When analysing the above introduced elements having a specific character of management in communication construction, one must indicate principal features such as exceptional complexity, considerable dynamic variability and a strong influence of the environment. The described conditions of operation substantiate the possibility of a vast improvement of the management process by applying an advisory system which, as opposed to the expert systems, enables the utilization of synergy resulting from a combination of 'hard' (e.g. the ability to collect, transmit and process an enormous amount of information/data) and 'soft' elements (the latter ensuing from typically human features like creativity, intuition etc. in the decision-making process), the application of which makes possible for the user/decision-maker to operate within the system in a dialogue mode.

The central problem consists of generating such control decisions concerning noise management for the analysed motorway section at appropriate time intervals (stages):

$$\left\{u_1^*, u_2^*, ..., u_{n-1}^*\right\} \tag{1}$$

to provide the average noise value at a permissible level (day/night):

$$L_{Aeq} \le L_{Aeq}^{perm} \tag{2}$$

at minimum cost, e.g.

$$E\left[\sum \varphi(u_i)j\right] = \min. \tag{3}$$

A highly subjective character of assessing noise effect considering people needs to be emphasized (there are cases of both an extremely enthusiastic attitude, e.g. a true passion for F-16 fighter in flight and exceptional sensitivity to even the slightest sound/noise). Besides, attention should be paid to possible changes in the attitude taken by the same person who reveals no negative disposition towards noise, however, since one has to take care of a child or elderly/sick person, s/he protests against the existing conditions of life/work etc. Hence, it is possible to introduce an alternative criterion of a decision consisting of reducing the number of persons exposed to the negative effects of noise within the given spatial and time range. The logical result of the above described regularities concerning noise perception by people will be to apply fuzzy logic (e.g. acceptable noise, noise is sometimes too loud etc.). The above presented model (1–3) seems quite simple but one can imagine a more complicated situation taking into account a different point of view conveyed by different groups of interests in the analysed area (compromise factors presented in Fig. 1 is an example of two groups of interests including peace lovers and local entrepreneurs and farmers interested in high underground water level keeping natural vegetation conditions) and peace lovers as the followers of underground highway placement for reducing noise emission (however, the level of natural underground water must be also reduced). Finally, for each elementary area, a ranking list of the groups of interests could be prepared considering a degree of the importance of each group, the conformity/non-conformity of different criteria etc. This problem may be analysed using the multi criteria decision-making method (Brauers *et al.* 2008; Jakimavičius and Burinskienė 2007; Morkvėnas *et al.* 2008; Thiel 2006 and 2008; Zavadskas *et al.*, 2006, 2007a, b, 2008b; Šelih *et al.* 2008, Peldschus 2008; Paslawski 2008c; Ginevičius *et al.* 2008a, b). It should be underlined that the prevision of all factors that could be dynamically changed appears very difficult and generate the risk of chaotic decision-making. The analysis of different management levels (a hierarchic approach) could be a chance to build a simplified model for each decision-making problem (Paslawski 2005).

3. Fundamentals of Noise Management

As mentioned before, considerable improvement has been made in noise management due to, first of all, two directives issued by the European Union (2002/49/EC, 2003/4/EC). It will be interesting to review either the current tendencies in noise management or to indicate the assumptions for the proposed advisory system against the background of typical decision-aiding (expert) systems.

Traffic Noise Management Policy prepared by the New Jersey Department of Transportation is an interesting example of noise management in the USA. It indicates three principal aims of activities:

- noise reduction at source,

- educational activities concerning traffic noise and correct spatial planning,
- means of preventing noise expansion.

As regards the first group, the indicated activities mostly included formulating appropriate State (regional) policies dedicated to using proper noise suppressors and road pavement (e.g. open grain structure in the vicinity of agglomerations). Educational activities are aimed, primarily, at making people aware of what noise is and how to approach noise problems and eliminate frequently encountered misconceptions in that field (e.g. it would be difficult to imagine environment returning to the conditions before constructing motorways in spite of various noise prevention means since the principal goal of a motorway is to enable fast transport). The third group of initiatives aimed at reducing noise emission/diffusion in the environment and is connected principally with improving the quality of life by designing new roads and motorways in a proper way and by modernizing the existing ones.

Another Noise Management Plan developed by the regional authorities in Sydney is very interesting from the point of view of the analysis examining the possibilities of having a dialogue with various groups of interests in noise management. Looking at different methods of informing local communities about planned noise hazards, development studies are among the preferred ones while meetings with inhabitants receive the lowest marks. The application of a dialogue on the Internet seems to be the most interesting from the point of view of the planned advisory system.

The management strategy worked out by the Scottish Airports is another example worth mentioning. It is distinguished by clearly defined goals:

- noise reduction (per one passenger) by 10% in 2005 as compared to the noise measured year 1996,
- reduction of night noise in each of the airports year by year,
- obligation to seek means/solutions for reducing noise impact at ground level (e.g. engine trials).

The principles applied in gaining the above-mentioned goals should be considered as particularly important. The most important one is the need to find equilibrium between reducing environmental impact and providing the necessary advantages of air travel (mainly economic and social ones). The remaining two principles including consultations (with both internal and external process participants) concerning the influence of the airport on the surrounding areas and preparing reports on airplane noise impact on the surrounding areas to be audited by independent outside organizations.

Disregarding any detailed analysis of the problems of implementing expert systems (Alter 2004; Alty and Coombs 1984; Briand 1988), it seems to be that the results of applying those were highly restricted in relation to the expectations (Bell 1985; Gabriel and Raut 1987; Gill 1995). According to the analysis of applying expert systems in engineering the process of building, the principal disadvantages were as follows (Zavadskas *et al.* 1995):

- problems of representing and processing knowledge from different fields (related to the interdisciplinary quality of work done by a construction engineer),
- explanations for expert systems are rather situation-specific and provide little information useful for the user,
- estimating the excess of system limits is a problem (risk of operation outside the expected limits),
- expert systems face the problems of solving conflicts resulting from the interdisciplinary quality of operations (conflicting interests of cooperating groups),
- there are no systems capable of learning automatically from examples on operating level,
- developing an expert system is very time-consuming.

The software used in developing an expert system seems to be a key problem of the successful implementation of such procedure. Certain authors enumerate the precise conditions of the successful implementation of expert systems (Duchessi and O'Keefe 1995):

- support provided by top management staff which should be considered a key issue due to the allocation of adequate resources,
- appropriately selected problem is particularly recommended to gain immediate advantages from system implementation (e.g. a system related to logistics enables the quick verification of its efficiency),
- users' approach is a definitively decisive factor in everyday use, although it is difficult to imagine realistic opportunities for the successful implementation of an expert system without meeting the above specified conditions,.

In this case, the author may refer to personal experience of implementing a logistic system related to prefabricated concrete units (Jasiczak and Pasławski 1989) where lack of accepting of the personnel site was the final hindrance of success.

The future of decision support systems in construction industry should be analyzed on the basis of three key elements: a general trend, methodology and a domain of application. General trends can be considered as the use of models with experimental rather than formal representation (Beynon *et al.* 2002) taking into consideration such human factors as ethics (Kaklauskas and Pruskus 2005) and human centred processes in decision making (Barthelemy *et al.* 2002) regarding risk and uncertainty at all management levels which is specific to construction industry (Mitkus and Trinkunienė 2008; Paslawski 2008a, b; Shevchenko *et al.* 2008; Matis 2008; Ustinovichius *et al.* 2006).

Regarding methodology (Liao 2005), Artificial Neural Networks (Wang *et al.* 2004; Basu and Maitra 2006; Miao and Xi 2008), Genetic Algorithms (Fu and Shen 2004; Mišauskaitė and Bagdonas 2006; Li 2008), sequential decisions (Mookerjee and Mannino 1997), fuzzy logic (El-Shal and Morris 2000) and simulation (Abacoumkin and Ballis 2004; Chtourou *et al.* 2005) were accepted as potential successful elements of hybrid DSS considering 'step-by-step' tracing of a decision process in the advisory system. Quality management systems, maintenance systems etc. mainly situated on operational and tactical levels in construction engineering management seems as potentially successful domains of application. The above mentioned tendencies give us a general basis for a hybrid advisory system presented in Figure 2.

The loops of learning mentioned in Figure 2 were considered for system development at three levels (Peschl 2007; Romme and van Witteloostuijn 1999):

1) the problems of management making corrections within the existing set of rules (for example: improving efficiency in flexibility tactics);
2) analyzing existing rules and procedures (for example: flexibility tactics A is the best option on situation X, isn't it?);
3) analyzing general context (for example: what is a key element of risk?).

4. The General Idea of FLENOMA2

If we resume the above presented circumstances of developing the advisory system for the management of traffic noise along the motorway section A2 near the city of Poznan, we can formulate the following key characteristics of the system:

- a cyclical character of decision-making due to the variable conditions of operation (e.g. the variable effectiveness of flexible noise reduction tactics according to the season of the year and changes in traffic load due to the extension of the motorway network;
- monitoring environmental impact on the achievements in the net technology, information transfer (wireless) and storage and processing enabling real-time operation;
- a hierarchy of decision making levels making possible an appeal to a higher level if the problem cannot be solved at the current one;
- learning as a necessary condition for knowledge acquisition and system development;
- flexibility due to adaptive and robust tactics enabling noise management in the turbulent environment.

The described general idea of the advisory system (Fig. 2) implemented in case of FLENOMA2 system was based on the presented assumptions of cyclical operation, monitoring, hierarchy, learning and flexibility. However, a flexible approach was the most important feature.

A flexibility application of FLENOMA2 system should be considered at three levels: operational, tactical and strategic. The operational level, first of all, will utilize the active approach using the traffic signs of changing contents (concerning, e.g. speed limits or directing vehicles to alternative routes like planned by-passes for S5 and S11 express roads – see Fig. 3).

Passive activities shall include traditional traffic signs (e.g. reducing travel speed at night). The above mentioned activities are supposed to reduce generated noise at operational level by reducing vehicle speed and limiting traffic itself (Bar and Delanne 1993). Tactical level may include both active and passive activities. The active ones will consist of constructing acoustic baffles (also in the form of noise suppressing greenery), heightening excavation embankments etc. Passive activities embrace, for example, the application of acoustic insulation in buildings (walls, floors, windows, doors etc.) in order to improve inside comfort (in offices, apartments, schools, hospitals etc.). Strategic level has been dominated by passive flexibility strategies: applying the pavements of reduced noise emission and planned areas reducing noise influence on people (e.g. buffer zones along the motorways where the construction of apartment buildings, hospitals, schools etc. would be prohibited).

The functioning of the system is based on the assumption of gradual improvement to the system following the principle of five stages corresponding to the Deming circle (Hamrol 2007) modified by adding the fifth element:

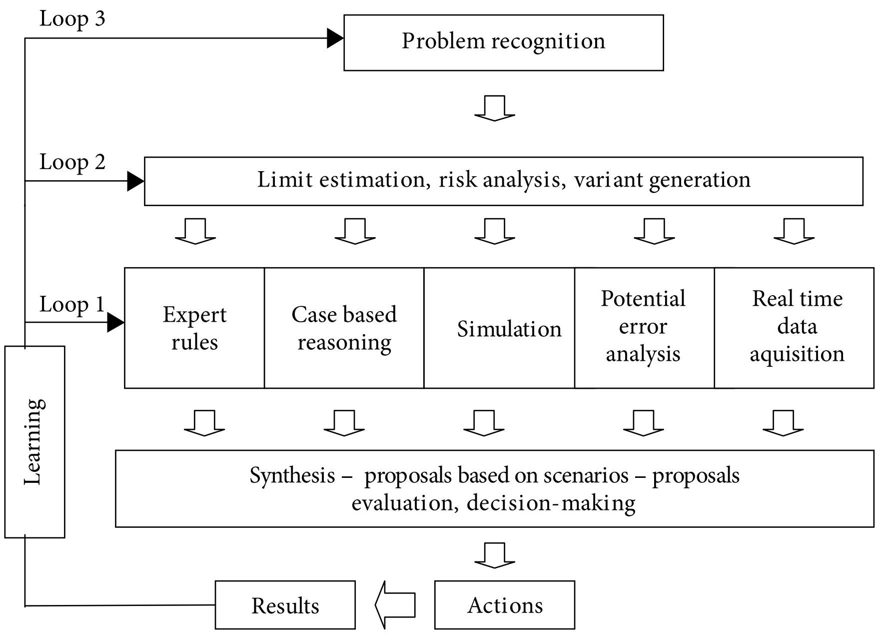

Fig. 2. The general idea of a hybrid advisory system

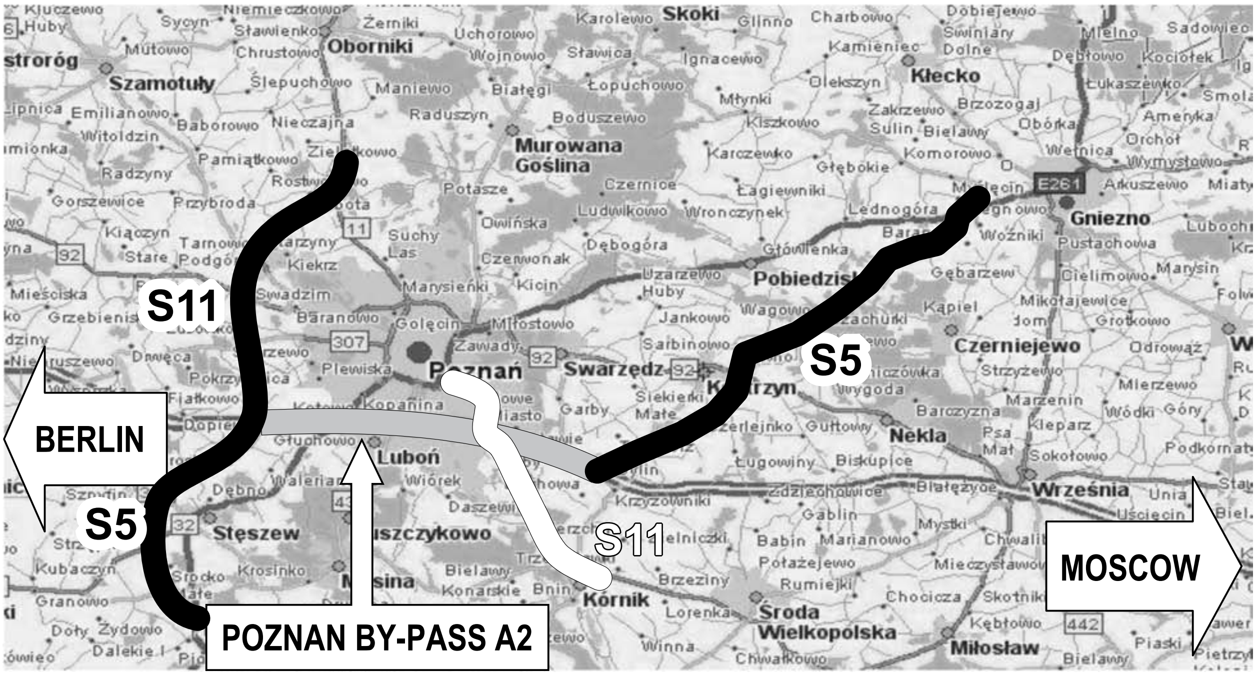

Fig. 3. The general idea of transportation system near Poznan (black colour – planned expressways S5 and S11, gray colour – POZNAN BY-PASS A2 in operation, white colour – expressway S11 in operation)

PLAN, DO, CHECK, REACT and LEARN for underlining the importance of the knowledge acquisition process.

The essence of the learning process is to foresee and prevent possible problems in the future. Considering the approach consistent with classic quality management, we could say that the sphere of activities related to detecting and correcting should be gradually limited in line with improving the system. The flexible approach puts emphasis on effectiveness (particularly economic ones), therefore exposing the hierarchy of management levels. The basic principle – in compliance with the theory of systems – is an attempt to solve problems as close to their source as possible (which is consistent with the assumption of the classic quality management theory concerning the growing costs of defect removal with growing distance from the realization place of production/service processes). Thus, engineering construction processes, where the influence of the environment exerts a huge impact on planning and executing processes on site, justifies an individual outlook on the quality management issues based on the flexible approach. We can summarize a gradual improvement of a quality management system simplifying it to a certain extent as aiming at a creation of a disturbance-proof system in which it would be possible to reduce detecting and correcting (as temporary measures) as much as possible due to appropriate preventive activities based on forecasting and monitoring. Such a goal can be achieved in a production system subjected to a highly restricted impact of its environment (quasi-closed system) where uncertainty, risk, variability etc. play no significant role. In the construction industry – due to its dependence on the changes in the environment as such – creating the described concept of achieving immunity may turn out to be ineffective and inefficient. A number of disturbances in construction processes are very difficult to predict not only due to their unpredictability (e.g. defect of a crane) but also due to errors in forecasts (e.g. weather forecasts concerning intensity, duration and a moment of precipitation occurrence). Hence, the flexible approach assumes the utilization of either active flexibility (consisting of adjustment to the predicted/ascertained conditions) or a passive one (immunity understood as providing the assumed results despite changing conditions of operation). The parity (utilization/application degree) of two principal flexibility components described above depends on the specific situation.

5. FLENOMA2 Case Study

When analysing noise management along POZNAN BY-PASS section of A2 motorway, one has to consider, first of all, dynamic changes in the network of express roads and motorways in the analyzed area and changing regulations concerning the use of the motorway (especially in regard to cargo transport). The following situations can be indicated from the point of view of conditions for A2 POZNAN BY-PASS functioning:

1) functioning of POZNAN BY-PASS section of A2 motorway as the Poznan's ring road – with very restricted access to the so-called old E8 Berlin–Moscow route;
2) connection to the Poznan–Konin motorway section of POZNAN BY-PASS;
3) including A2 POZNAN BY-PASS in the route of Berlin–Moscow toll motorway – connection to the Western section [Poznan–Nowy Tomysl] of A2 motorway;
4) a planned extension of the Western motorway section to the border with Germany (although no decision was made at the time of writing this paper, however, we can expect that the a/m

section of the motorway will be completed before EURO 2012 games);
5) an extension of the Eastern motorway section to Warsaw and further to the border with Belarus;
6) linking A2 and A1 motorways (only in this case A2 POZNAN BY-PASS will be really linked to the elementary motorway network);
7) an extension of two Poznan's ring roads: Western road linking the Northern section of S11 express road to Kolobrzeg with the Southern section of S5 express road to Wroclaw and Eastern road linking the sections of two express roads - the Southern section of S11 to Katowice and the Northern section of S5 to Bydgoszcz.

I may assume that the above described stages (1÷6) of developing the system of express roads and motorways will contribute to the intensification of traffic on A2 POZNAN BY-PASS section (as a toll-free element of A2 Berlin–Moscow toll motorway), and therefore to growing motorway noise. In case of the last option, it is possible to reduce transit by A2 POZNAN BY-PASS due to the utilization of direct connections to S5 and S11 motorways (Fig. 3).

The following problems shall be taken into account when analysing the case of the section of A2 motorway near Poznan:

- a tendency to reduce traffic noise due to a gradual improvement in car production technologies, better pavements and increased requirements for customers/users, tightening noise emission regulations etc.,
- a general tendency towards gradual traffic intensification at the toll-free A2 BY-PASS POZNAN section as a result of connecting other roads (an extension of A2 motorway towards the border and Warsaw–Moscow as well as connecting S5 and S11 express roads), economic growth in Poland and elsewhere and because of transit traffic (mainly in the East–West direction),
- frequent changes in regulations concerning motorway toll for trucks (the latest change is supposed to restore toll payment for trucks that will generate traffic reduction).

Consequently, the tendency towards ever growing traffic and noise at the analysed A2 POZNAN BY-PASS section cannot be considered as certain, hence the need to apply the flexible approach towards noise management is reasonable.

The purpose of the proposed FLENOMA2 system is to facilitate making decisions connected with noise management in the urban environment of A2 POZNAN BY-PASS. The goal is affected by two basic activities:

- implementing flexibility options aimed at adjusting the level of noise around the motorway to relevant requirements,
- keeping population properly informed about the current and expected noise risks (noise/acoustic maps) and maintaining dialogue (the Internet dialog box) including the representatives of various groups of interests in order to find compromise solutions sufficiently satisfactory to all interested parties.

The following points obtained from various sources must be emphasized after analyzing data on noise risk in the vicinity of A2 POZNAN BY-PASS:

- high dynamics of traffic intensity growth (Kolaska 2007);
- growing social awareness of harmful effects on noise and willingness to fight for one's rights (for example, the recent cancelling of Poznan Air Show or the Danish speedway championships and the introduction of new take-off procedures for F-16 fighters);
- higher noise management problems occur on access roads (parallel) to the motorway which seems to result from the absence of predictions about such a high traffic level at the stage of building permit issuance (a situation a few decades ago).

To sum up, considerable noise risk (Gorka-Czajka 2008; Kolaska 2007) is not a direct effect on the motorway but rather on the local streets (Table).

Undoubtedly, it is connected with considerable expenditures on improving acoustic climate around the motorway (about 150 thousand trees and bushes, acoustic baffles ca 4 km long, 520 m^2 of sound insulated windows etc. (Chodorowski 2001)).

It should be also mentioned that a principal assumption of ever growing noise due to the avalanche scale of traffic increase at A2 POZNAN BY-PASS section and the adaptive approach (Paslawski 2008a) based on such hypothesis do not need to be realized in the near future.

Noise monitoring results for BY-PASS POZNAN A2

Point	Day/night	Year 2006	Year 2007	Result analysis
P1	Day, $L_{Aeq\,16h}$	61.9	61.7	Minimal exceeding at day and night consequential with traffic apart from highway
	Night $L_{Aeq\,8h}$	56.4	57.9	
P2	Day, $L_{Aeq\,16h}$	56.0	56.7	No exceeding
	Night $L_{Aeq\,8h}$	51.1	52.9	
P3	Day, $L_{Aeq\,16h}$	67.0	66.1	Exceeding on 6÷7 dB a day and on 7 dB at night (traffic apart from highway)
	Night $L_{Aeq\,8h}$	62.6	62.4	
P4	Day, $L_{Aeq\,16h}$	54.1	51.1	No exceeding
	Night $L_{Aeq\,8h}$	55.0	52.7	
P5	Day, $L_{Aeq\,16h}$	67.7	67.8	Exceeding on 8dB a day and on 8÷9 dB at night (traffic apart from highway)
	Night $L_{Aeq\,8h}$	63.1	63.9	

Remarks: The uncertainty of measurements carried out +/- 1
Source: WOIS (Provincial Inspectorate of Environmental Protection)

We must also take into account the scenario of noise reduction, for example, truck traffic restrictions. Such position justifies the application of a flexible approach (particularly at operational level) providing the possibility of achieving the assumed effects according to the situation. For example, it may be possible to increase speed limit in case of low traffic which would facilitate a compromise between the interests of motorway users and those exposed to traffic noise in the urban environment. It is worth emphasizing that FLENOMA2 advisory system was designed with a hierarchic structure which assumes transferring the problems of noise management gradually from lower to higher levels.

6. Conclusions

The above introduced and described approach to noise management illustrated by the case study allows formulating the following conclusions:

1. Noise is perceived as a particularly obnoxious factor of pollution of the human environment affecting much more than a narrowly considered hearing system.
2. In view of numerous contradictory decision criteria, it is necessary to adopt the strategy of compromise solutions (taking into account, e.g. the speed and intensity of traffic as noise generating factors, economic goals of the motorway operator and social goals as the availability of fast transport).
3. The flexibility of noise management is justified in view of changing noise emission levels connected with modifications in the system of roads and motorways, changing regulations concerning heavy transport and the need to adjust to variable weather conditions (humidity, wind etc.).
4. The problem of noise management can be considerably simplified by extensively informing population about the existing and expected (e.g. within the range of 10–20 years) noise level in a given area.
5. The role of individual responsibility for motorway noise management consists not only of looking for preventive means but also of maintaining a dialogue between various participants in the decision-making process in order to find compromise solutions and of distributing knowledge about the nature of noise and methods of suppressing it (e.g. the application of reduced noise emission pavements reduces noise by 3dB).
6. Spatial planning in the motorway area should be considered as the key element – it is much simpler to locate a given object correctly (e.g. hospital or hypermarket) than to try to achieve the assumed goals in an inappropriate place/environment.
7. Due to the flexible approach, it is possible to operate in two directions: to improve life comfort of the inhabitants/employees exposed to noise and to maintain a general goal of the by-pass (fast traffic on the motorway) accordingly to the current changes in the situation.

The hierarchic structure of the system offers the possibility of undertaking appropriate activities at a given management level (starting from the lowest one), whereas in case of lack of possibility, to solve a specific problem at the analysed level, i.e. to transfer the problem to a higher level and to overcome it applying other means.

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