Nationaal Lucht- en Ruimtevaartlaboratorium

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NLR-TP-2012-404

Strategy for development of airport noise enforcement models

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Executive summary

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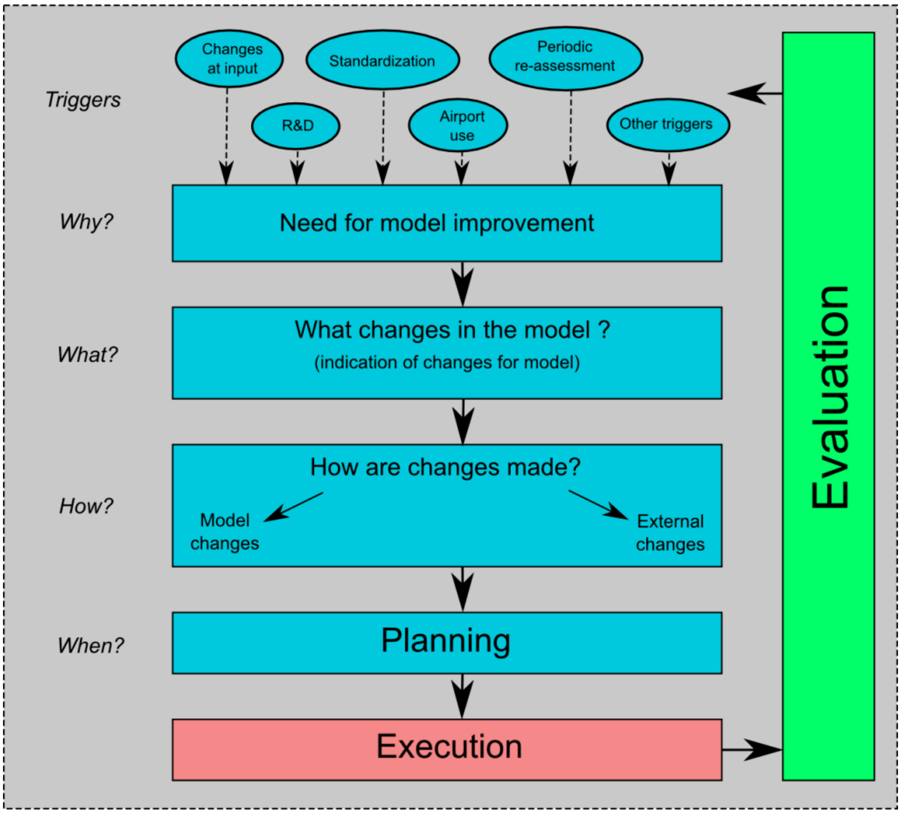

Report no.
NLR-TP-2012-404

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Report classification
UNCLASSIFIED

Date
September 2012

Knowledge area(s)
Vliegtuiggeluidseffecten op de omgeving
Externe Luchtvaart Veiligheid en beleidsondersteuning

Descriptor(s)
geluid
beleidsondersteuning
geluidsmodellering
vliegtuiggeluid
milieu

Problem area
Progressive research on aircraft noise triggers continuous improvements in current noise models. These improvements are done both for models that evaluate one single flight (single-event models), and for models that consider the effect of large numbers of flights (multi-event models). The multi-event models are typically suited for policy support purposes and are in some countries also part of legislation. Hence, the question rises whether model developments are desirable from a policy perspective, when the model is formally part of legislation?

Description of work
NLR conducted research on how to deal with technical model improvements for single- and multi-event models taking the policy perspective into account. Several existing models are considered for aircraft noise having different applications: enforcement, noise

This report is based on a presentation held at the Inter Noise 2012 Conference, New York City, USA, 19–22 August 2012.

mapping, forecasting of traffic noise, etc. An overview has been created including these model purposes and their specific requirements. Also, the use of multiple model implementations, and the policy how to address them, is discussed. To deal with the introduction of new models or model improvements, a strategy to implement them in an orderly and reproducible manner, including societal and legal implications, is described. A key part of the strategy is to accept and to communicate the reality that models are subject to continuous improvement.

Results and conclusions
The presentation and the use of a process for model improvement provide a framework to explain why updates in noise models take place, and how they are implemented. This makes it clear to all aircraft noise stakeholders that predetermined events trigger changes in the noise modeling. The process leaves room for the legislator to decide *how to* actually implement a model improvement, e.g. to prescribe the use of verification methods, test cases, reference implementation, or to dictate an implementation to make sure the intended model (specification) is used. Next, a time planning must be made that aligns research work, policy process, noise software development or adaptation, stakeholder management (involvement and communication), and publication of the measures. Preferably, the overall message within the strategy is to accept and to communicate the reality that models are subject to continuous improvement whatever their application.

A further study can be done in the area of stakeholder interests: how can model improvements be objectively and effectively communicated, evaluated, and discussed with all airport stakeholders? And what other parts of legislation is concerned with the use of the airport? The use of input data also has a significant influence on the outcome of an applied model. With new developments such as the availability of actual radar tracks and improved performance data of aircraft, how will the results of noise models improve? NLR is doing continuing research in this area and works on answers to these questions.

Applicability
Noise models can have a number of different applications, and in this paper the focus is on purposes of enforcement and policy support.

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Customer	Directoraat-Generaal Bereikbaarheid
Contract number	-----
Owner	NLR
Division NLR	Air Transport
Distribution	Unlimited
Classification of title	Unclassified
	September 2012

Approved by:

Author	Reviewer	Managing department
Roalt Aalmoes	S.J.Heblij	R.W.A. Vercammen
Date: 24-09-2012	Date: 24-09-2012	Date: 24-09-2012

Summary

Progressive research on aircraft noise triggers continuous improvements in current noise models. These improvements are done both for models that evaluate one single flight (single-event models), and for models that consider the effect of large numbers of flights (multi-event models). The multi-event models are typically suited for policy support purposes and are in some countries also part of legislation. Hence, the question rises whether model developments are desirable from a policy perspective, when the model is formally part of legislation?

NLR conducted research on how to deal with technical model improvements for single- and multi-event models taking the policy perspective into account. Several existing models are considered for aircraft noise having different applications: enforcement, noise mapping, forecasting of traffic noise, etc. An overview has been created including these model purposes and their specific requirements. Also, the use of multiple model implementations, and the policy how to address them, is discussed. To deal with the introduction of new models or model improvements, a strategy to implement them in an orderly and reproducible manner, including societal and legal implications, is described. A key part of the strategy is to accept and to communicate the reality that models are subject to continuous improvement.

Contents

1 Introduction

Since the use of the aircraft for commercial purposes, the growth of traffic has resulted in increased noise pollution around airports. In combination with the growth of the population (sometimes even higher around economic areas like large scale airports) make policy support important for dealing with both the (positive effects of) growth and the (negative effects of) noise pollution that it causes.
Aircraft noise models serve to predict the noise or enforce limits of the noise that is generated. With single-event models, one specific aircraft or route can be examined and measures (allowing or not, rerouting, etc.) can be taken. With multi-event models, a number of movements (e.g. a day, a month, a year) are accumulated. The latter method predicts the noise for a wider area and is used for enforcement purposes in countries like The Netherlands for already more than 30 years[1]. Therefore, a change in the model can mean a change in enforcement.

Research (and the resulting improvements) of noise models and enforcement of noise limits usually ask for different updating strategies. When the same model is used for both research and enforcement, this might lead to contradicting views on when and how often to update the model. The research or laboratory model can be updated frequently after a change has been validated to be an improvement to the model. A legal enforcement model needs stability and frequent changes are undesirable. A process leading to answers to the questions when and how to change noise models has been described before[2], where the following general guidelines can be distilled:

- Noise model software changes that do not have impact on noise limits may be done within an enforcement period.
- Changes that can have an impact on noise limits now or in the future are advised to be made after an enforcement period when both model software and noise limits are updated.
- Any other changes (e.g. discrepancies) do not have standard guidelines and should always be carefully assessed if they are applied within an enforcement period.

A recommendation from this same reference that deserves special note is that it is advisable to adopt a transparent process for updating noise models that spans a period (e.g. 5 years) during which noise models are evaluated as they are living entities.
This paper will describe a strategy for noise model development, not only small updates, but also the choice and implementation of new noise models. A key element of implementation of a new model is the way how this new model can be kept up-to-date.

2 Models and their applications

Noise models can have a number of different applications, and in this paper the focus is on purposes of enforcement and policy support. This section describes two possible model applications, namely Enforcement and Noise mapping.

2.1 Enforcement

The first model application considered is enforcement and has a legal embedding. The model is used to quantify the level of *environmental protection*. In other words, calculated results are used for the enforcement of legal rules and regulations. Thus the noise model becomes an objective means to determine if an airport is operating within the maximum limits. In this way, the operational variables of the model can be considered policy steering options. I.e. when aircraft become quieter, more operations fit in the same noise contour. This stimulates airports and airlines to optimize their operations for noise output and airlines will require quieter aircraft from their manufacturers.

The effectiveness of the model to show the effect of the steering options depends on availability of input data and availability of simulation techniques. For example, if an exhaustive set of track data (of arriving and departing aircraft at an airport) is not available, only a nominal route can be determined. The model can determine a route distribution according to research done in the past and use it as an approximation of the actually flown tracks, see Figure 1. However, a policy maker may want to create an incentive for flying of the preferred route to reduce the noise impact: it may require that the actually flown tracks are taken into account in the result, so the effects of actual operations on the noise impact are shown. Thus, the enforcement model should make use of its full policy/enforcement potential, in a way that the effects of operational improvements are shown in the results.

A key characteristic of enforcement noise models is to enable uniform calculations leading to consistent results. Each user should get the same result, which means the model and technical input is documented in great detail. And although the model aims to calculate the actual noise in decibels, it is of less interest to the policy maker whether the noise levels represent reality than whether the model produces consistent results. From an operators point of view the captured large degree of detail is also desirable. He will predict the number of operations beforehand to stay within the noise limits. Any extra variable makes the estimation less accurate and may become an operation and therefore a cost risk.

Noise models not only calculate noise that occurred in the past, noise mapping specialists use traffic forecasting methods to predict future noise as well. These methods offer a necessary tool to determine beforehand if future use of the airport is permitted according to the regulations, or where issues might be expected. Policy makers can then apply steering measures to reduce the noise impact of the operations to stay within the limits or to accommodate air traffic growth.

2.2 Strategic Noise Maps

The second application considered is strategic noise mapping. The European directive 2002/49/EC [3] requires member states to generate noise maps for amongst others major airports and agglomerations within their territories every five years. National policy makers also need to make action plans to reduce the noise impact, e.g. the number of people exposed.

The focus of the strategic noise mapping application is to indicate the areas in which many people are highly exposed to noise. This indication leads to new policy that can be created to reduce the noise with the help of action planning. In the end, a European level playing field is created in the future, where the results should be comparable. Each user should get similar (not necessary the same) results. To create this level playing field assessment steps and calculations methods are to be harmonized, which is an ongoing process at the moment.

3 Research on noise models for policy making

Research is not finite, nor is research on noise models. New insights on noise pollution or improved data on noise measurements trigger new developments and may ultimately lead to better models that predict noise pollution. For a policy maker, these new models do not necessary mean an improvement: it means that the currently used models are not up to date and may not always predict the actual noise pollution. A modification process may become cumbersome with many stakeholders having different views and opinions on why the modification is being made: a civilian living next to the airport has a different interest than an airport authority or an airliner.

However, a policy maker also has something to explain when outdated models are used and the results do not reflect the noise climate as generated by the real traffic. A pro-active attitude keeps the policy maker in control of new developments by assessing new developments and deciding what research will be adopted and for what reason.

4 Triggers for model changes

It is assumed that a noise model satisfies the policy maker's needs, until limitations become apparent. These limitations may come in small steps that accumulate, or a significant development may take place. The following, not necessarily exhaustive, list of triggers indicate that a change for the use of a model be necessary:

1. *Improved research*: New insights of noise modeling covering all aspects regarding the source, propagation path and receiver show that the current models do not (accurately) represent the actual noise that is being produced. For example, research based on measuring the actual noise of an aircraft[5], trigger new noise model developments.
2. *Change of input*: A noise model makes use of a number of different inputs. Most noise models are based upon reference noise data made available by aircraft or engines manufacturers or through noise measurements made by third parties. When this data is updated or added for new aircraft types, the model using it can generate different results. In some situations, the input data set is separate from the model and it can be changed independently[6]. Other input data may change as well, and thus trigger changes to the modeling.
3. *Change of airport use*: A significant change in use of the airport will not occur often but will have a significant impact on noise calculations: not only the fleet mix will change; also the pre-determined boundaries where the noise will occur may need to be re-evaluated. A change of model here can occur if the previously used model is not well suited for the new airport use, e.g. if the model is not able to show the effects of improved operations.
4. *National or international standardization*: Although this is mostly the result of ongoing research, the policy maker may want to change or adapt the local or national policy to a policy that is compatible with either (internal) national or international developments. An example of (internal) nation developments is the standardization of sound measurements across different industries by using Lden and Lnight[7]. Two examples of international developments are the adoption of the European Directive 2002/49/EC [3] and the introduction of ECAC Doc.29 [4].
5. *Periodic re-assessment*: One or more of the triggers mentioned above may be postponed until a suitable moment occurs. At such a moment, preferably scheduled in advance to enhance the transparency of the process, the policy maker can start a process of changing the noise model.

5 Implementations of models and consequences for legislation

From a policy perspective, decisions are made based upon the results of a model. This model is fed with a set of input data. In Figure 2, the reference situation of input to a model, the model itself, and the output of the model, the result, is shown. But a model is only a specification of how the input is transformed into the result. If this situation is translated to the real world, the input will become the *available input*; the model will become an *implemented model*; and the result is the *result that is generated* by the implementation of the model. This last result can be, but is not necessarily, the same result as intended by the original model.
Therefore, a model (specification) is translated into an implementation to make it useful for a certain application. In an implementation, design choices are made by developers based upon intended purpose of the model (research, commercial product, etc.), existing knowledge of the implementation platform (e.g. programming language or system platform), amongst others.
If legislation is based upon a model implementation, not only changes of the model itself, but also changes in the implementation must be taken into account.

From a legislation point of view, the process becomes even more complicated when more than one model implementation exists. This situation is not uncommon where different usage of the model is required and different parties (companies, research institutes, standardization bodies) are involved.
Results created with one implementation may not necessary generate (exactly) the same results as another implementation. The following strategies can be used to ensure similar results or reduce the differences between implementations:
Verification efforts are activities where the results of an implementation are compared against the specification. Verification can take place at different levels. A strong verification method is by comparing the result with the specified result. But verification can also take place at a more modular level where intermediate results are evaluated to see if they are consistent with the model. A special way of verification is the use of *published test cases* that indicate a required outcome. The advantage of these test cases is that those implementing the model can do much of the verification by themselves.
A *reference implementation* is also a means to define a model. This implementation is not optimized for a specific application, but it generates desired results and can be used already during the definition of the standardization process itself. In the telecommunication and computer science industry, the use of a reference implementation is common practice[8].
If unspecified behavior is encountered in a model, this means that there is room for different interpretation. This interpretation can be done by the implementer of the model. To prevent different interpretations by different implementers of model, *a decision can be made* by the

policy maker how to deal with this uncertainty. In essence, this is an extension of the model specification.
Finally, a measure that can be taken is the *dictating of a specific model implementation*, by a legislator. This prevents different outcomes and keeps results more consistent. However, in case of unspecified behavior, the implemented behavior is implicitly chosen and may inadvertently become part of the model. It is also not always possible to mandate one single implementation where multiple applications are involved with multiple parties using them: a single implementation can have limitations on the input set to be used, the parameters of the model that can be changed, and a model may not have enough (detailed) results for the application that the model is used for. Making a model implementation that takes all different and future usage of the model into account can be difficult if not impossible.

6 Process for model improvement

Before a new (or updated) model is introduced, the classic four questions, relating to the reason, the magnitude, the way, and the time frame, must be answered:

- *Why* is a new model needed?
- *What* will change in the new model?
- *How* is the new model introduced?
- *When* will the change take place?

In Figure 3, the relation between these questions is displayed, together with the execution phase of updating a model and a feedback loop, the evaluation. The figure depicts a flowchart of the strategy to be followed in this paper.
The reason (*Why?*) is not only important for the policy maker, but for the stakeholders of the airport as well. Communities living around the airport can be skeptical to changes, as can be airport authorities and airlines that have economic interest with their activities.
The magnitude (*What?*) of the changes should be a result of the triggers mentioned in section four (Triggers for model changes). But even with a published standard such as ECAC Doc.29 [4], there are still implementation choices that must be filled in.
The way (*How?*) is the most important question that has both internal as well as external implications. The internal implications are related to how the model is changed, what (technical) solutions can be applied to make sure the model is improved.
The external implications depend strongly on the local or national situation; a country with a dense population living around a European top-5 airport, such as the Netherlands, has a longer history of growth, positive and negative interests by the community, and therefore has a more strongly regulated and controlled process than a country with lower population density around airports or with little influence by the community, due to their political system. The development of a country's legal and societal system also influences what role regulation plays and how well local communities in the vicinity are organized.
The time frame (*When?*) looks like the easiest of the four to define, but requires a planning that aligns research work, policy process, noise software development or adaptation, stakeholder management (involvement and communication), and publication of the measures. A delay in either one of these processes may disturb the overall process and result in undesired delay, ranging from delay of development in or around airports, delay in updated airport usage plans, or even national penalties because of international non-conformance in case of international regulations.
As an example, the introduction of Doc.29 for European regulation shows that first research is performed to develop the Doc.29 standard. After that, European regulation indicates a recommendation for the use of Doc.29 to the member states[3]. Followed by the recommendation,

member state will perform own research and implications for their local situation, and European efforts take place to develop one or more Doc.29 model implementations, such as work done in the ANCAT AIRMOD work group. At this moment (2012), it is expected that Doc.29 will be the model that is prescribed by the European Commission as the standard model to calculate aircraft noise around airports in Europe.

In the execution phase, the new model (or model update) will be introduced and the noise model will be used for its various applications (see for two examples, Section 2). This phase will be active for as long as the new model (update) is being used, while it will be subject of intentional or unintentional evaluations. These evaluations may result in actions to be taken and can lead to new triggers that feed new model updates. And so, the process of model improvement starts all over again.

7 Conclusions and discussion

The presentation and the use of a process for model improvement provide a framework to explain why updates in noise models take place, and how they are implemented. This makes it clear to all aircraft noise stakeholders that predetermined events trigger changes in the noise modeling. The process leaves room for the legislator to decide *how to* actually implement a model improvement, e.g. to prescribe the use of verification methods, test cases, reference implementation, or to dictate an implementation to make sure the intended model (specification) is used. Next, a time planning must be made that aligns research work, policy process, noise software development or adaptation, stakeholder management (involvement and communication), and publication of the measures. Preferably, the overall message within the strategy is to accept and to communicate the reality that models are subject to continuous improvement whatever their application.

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8 Acknowledgements

The authors would like to thank the Dutch ministry of infrastructure and environment for the discussions and thought on this subject, Sander Hebly for reviewing, Henk Veerbeek for providing a graphical representation of routes, and Jos Dolderman for providing corresponding references.

References

1. P. Scheeper, H.J. Poutsma, D.J. Rozema, “Voorschrift voor de berekening van de geluidsbelasting door vliegtuigen”. *Report by NLR, LL-HR-20-01,* The Netherlands, November 1980.

2. Annette Kruger-Dokter, Jos Dolderman, “To update or not to update noise limits, that is the question”. *40th International Congress and Exposition on Noise Control Engineering 2011 (Internoise 2011),* Osaka Japan, 2011.

3. Directive 2002/49/EC of the European parliament and of the council of 25 June 2002. In *Official Journal of the European Communities*, L 189/12-25, 18 July, 2002.

4. ECAC.CEAC Doc 29, *Report on Standard method of Computing Noise Contours around Civil Airports*, Volume 1&2, 3rd Edition (2005).

5. Dick Bergmans, Michael Arntzen, Wim Lammen. “Noise attenuation in varying athmospheric conditions”. *40th International Congress and Exposition on Noise Control Engineering 2011(Internoise 2011),* Osaka Japan, 2011.

6. G.J.T. Heppe. “Appendices van de voorschriften voor de berekening van de geluidsbelasting in Lden en Lnight voor de overige burgerluchthavens bedoeld in artikel 8.1 van de Wet luchtvaart”. *Report by NLR*, NLR-CR-96650 L Versie 12, Amsterdam The Netherlands, March 2011.

7. Kjeld Vinkx, “Eisen voor gelijkwaardige bescherming bij wijziging van de Luchthavenbesluiten”. *Report by To70,* for: de ministeries van Verkeer en Waterstaat en van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, The Hague The Netherlands, May 2007.

8. Reference implementation. In *Wikipedia*. Retrieved May 10, 2012, from http://en.wikipedia.org/wiki/Reference_implementation.

Fig. 1 Graphical display of a route distribution (purple zone) for a departure route, and a sample of actually flown tracks for that route (blue). Above a predefined altitude and upon instruction, the aircraft are allowed to depart from the route.

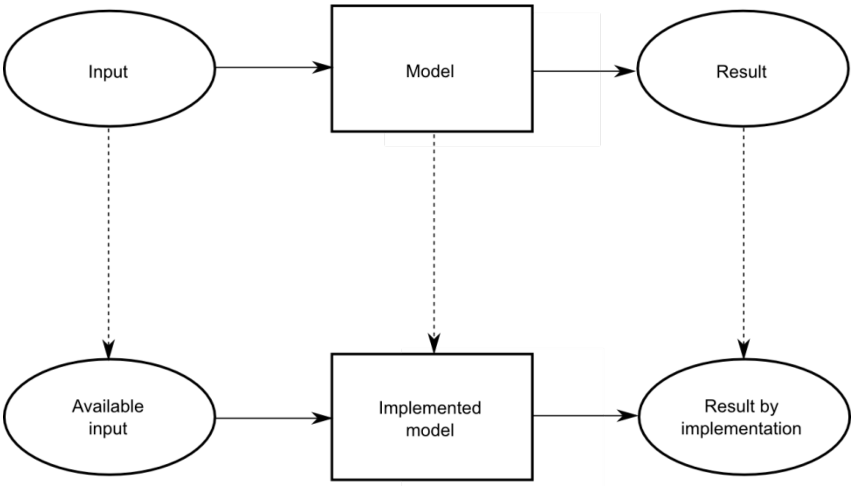

Fig. 2 The difference between a model with its input and result, and an implementation of that model.

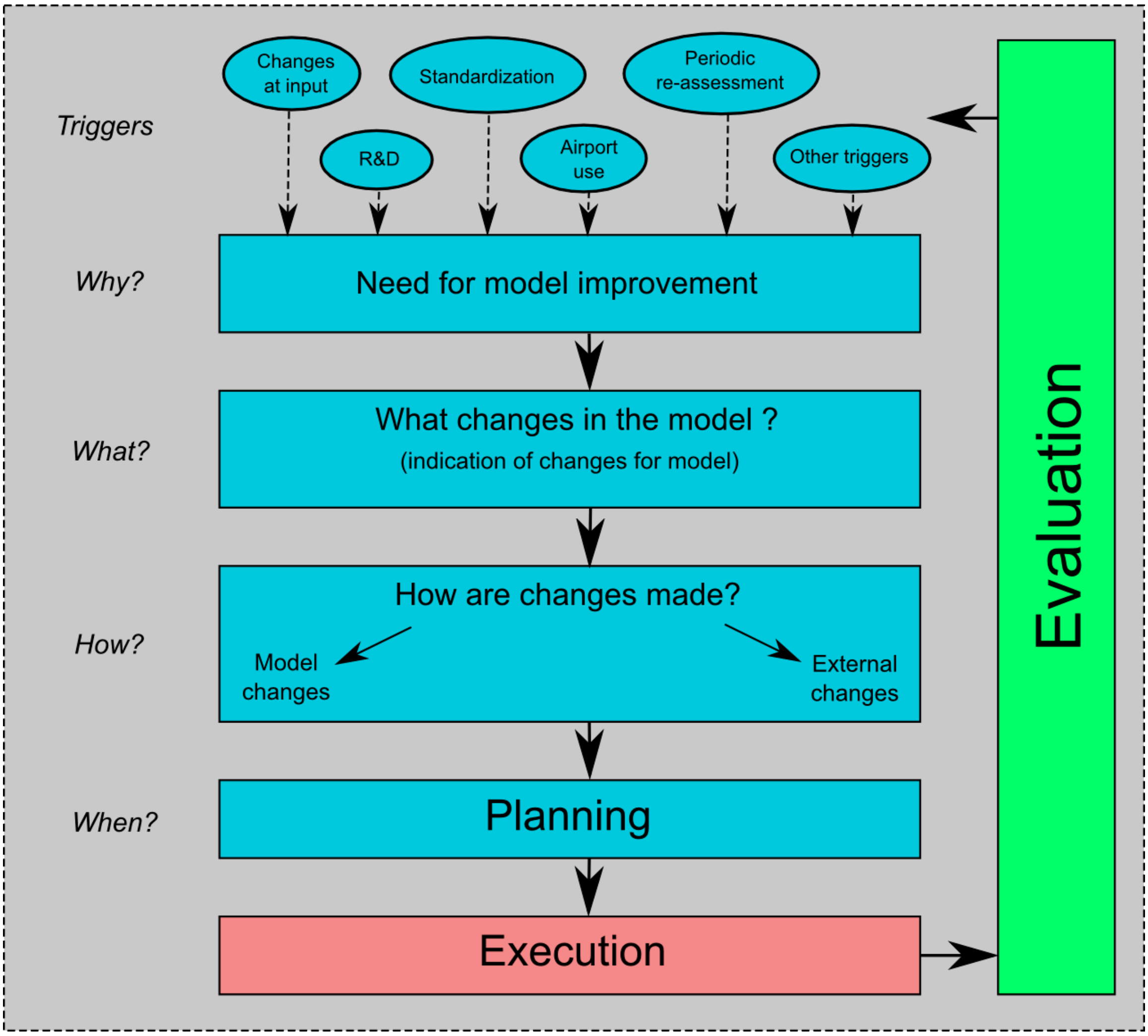

Fig. 3 Graphical presentation of the model improvement process.