Improving the Tools of Flow Analysis

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1 Introduction

The work focuses on clarifying the law of increasing the efficiency of matter, energy and information flows, and improving the methodology of flow analysis.

The paper analyses the flows in the system and formulates recommendations for increasing the practical value of the results of flow analysis by changing the wording and conclusions of the current version of the "law of improving the efficiency of substance, energy and information flows" as edited by S. Litvin and A. Lyubomirsky. Recommendations are also made to improve the methodology and procedure of flow analysis.

1.1 Relevance of the research topic

1.1.1 The aims of the study

The purpose of this paper is to improve the instrumentality of the flow optimisation law and to develop a practical algorithm for flow analysis.

1.1.2 Overview of known approaches to this problem

Law of Flow Optimisation

The precursor of the law in question is the one formulated by G. Altshuller The law of minimum energy conductivity of systems [1]. In the course of system development The LRTC Act has been around for a long time (from 1975 to 2002, based on publication dates) has remained virtually unchanged. In particular, in [2, p. 1,56] the law is briefly mentioned as part of the law of increasing coherence in systems; Y. Salamatov [3] reproduces the law almost verbatim.

The experience of practical application of the law has led to attempts to improve it. The first work that independently analyses flows from the TRIZ point of view is an article by Y. Hotimlyansky [4]. In V. Petrov's book [5], the law is considered as an increase in specific energy saturation of systems and is a sub-trend of the law of system transition to microlevel. But here it is no longer considered as a requirement of the minimum necessary level, but precisely as a line of systems development.

Then I. Gridnev [unpublished, as reported by A. Lyubomirsky] put forward the idea of extending this law to the whole lifetime of the system. He found that in the process of TC development the conductivity of its parts carrying energy flows usually increases, and identified mechanisms providing this increase in conductivity.

That is why this version of the law is called the "Energy Conduction Enhancement Law".

S. Litvin's work [6] extended this approach to matter and information flows as well. Litvin and Lubomirsky [6] extended this approach to matter and information flows as well. The "Law of increasing conductivity of matter, energy and information flows" (in abbreviated form – simply "Law of increasing conductivity of flows") appeared in their proposed system of laws of technical development. This version is the most widespread and is the one chosen as the prototype for further work.

It is not difficult to see that with S. Litvin and A. Lubomirski this is essentially a completely new law, not so much developing the predecessors as being next to them, since:

- This version of the law does not talk about the possibility of a system, but about ways to improve an already working system
- The range of flows to be considered is considerably extended from energy to all types of flows existing in the system.

The description of the law in [6] contains not only a definition of the law itself (trend), but also a list of sub-trends (lines of development). They are essentially a set of recommendations to improve flows in the system. The list of sub-trends is quite extensive and consists of 42 items. They are structured according to the type of flow and the division of mechanisms into "changes in the conductivity of flows" and "changes in the efficiency of flows".

Streaming analysis

Flow analysis has emerged and become widespread as a tool that complements the weaknesses of Functional Analysis (FA) well. FA appeared in TRIZ as a tool for finding the 'right' weaknesses [7, 8]. However, in addition to FA proper, the so-called "functional approach" has also quickly entered the market and has produced (and continues to produce) highly effective derivatives.

The reasons for this are clear. In contrast to the traditional component-by-component approach in engineering practice, the functional approach allows:

- Consider the task from a different perspective, that is, to remove the block of psychological inertia,
- Abstraction for a while from the device of specific components and focus on the functions they perform.

The FA system is described in the form of a graph whose nodes are the components of the system (whose structure is not disclosed), and the links are the functions performed by the components. In this case, the links of the graph turn out to be elementary machines described in terms of "object – function – subject". While seemingly oversimplified, the approach is so productive that, for example, it has become one of the key elements in the GEN3:ID methodology.

Flows in a technical system are specific components. The main feature of flow as a component is the distributed (in space and time) parameters. The other components of the system (stationary) are localised in space. Because of this distinction, flows are extremely inconvenient to fit into a functional approach. Therefore, a special tool – flow analysis (FA) – has emerged.

A basic workable PA algorithm is described in [9]. Although only published in 2010, the flow analysis methodology described therein has been effectively applied by companies in GEN3/Algorithm since at least 2003. In spite of the quite decent effectiveness of the methodology, specialists of GEN3/Algorithm have made several attempts to improve it. In 2008, A. Efimov showed the possibility of combining PA and FA in process analysis [10]. In 2009, A. Kashkarov in his dissertation work presented a variant of combining flow and functional analysis [11]. In 2010, V. Vasiliev in his unpublished work "Methodology of Energy Flow Chains in Mechanical Vehicle Systems" considered sequential flow transformation in the system.

Problems and shortcomings of existing methodologies

In general, the combined use of FA and PA has consistently produced good results. However, experience from their practical application suggests a number of problems and shortcomings. At the level of PA proper, these are:

- Lack of a coherent flow parameterisation algorithm (analysed in detail later in the text).
- Lack of specific guidance to select one of the 42 available sub-trends.
- Difficulty in correctly separating harmful and parasitic flows in the system.
- Incorrect application of the concept of "flow conductivity" (analysed in detail later in the text).

At the level of interaction between FAs and PAs

- Lack of an unambiguous link between the elements of the functional and flow model, making it difficult to formulate key weaknesses
- There is no relationship between the parameters of the FM elements and the flows, which makes it difficult to formulate requirements for the parameters of the elements.

In addition, the underlying papers almost completely separate the procedures for compiling a flow model and analysing this model. Thus, in O. Gerasimov's paper [9], after a detailed description of model building, it says "Carry out flow model analysis", followed by literally a few lines reflecting the main headings of the relevant chapter from the work of S. Litvin and A. Lyubomirsky.

The work of S. Litvin and A. Lyubomirsky [6] states:

- Select flows and their links with which there are significant disadvantages.
- Select the mechanisms of law that make sense to apply to address the shortcomings.
- Selection criteria: results of previous analysis, availability of resources".

The first step in this process is the selection of the flows to be analysed, which is not mentioned at all.

This paper combines these two parts of the paper: model building and model analysis.

1.2 A detailed problem statement

In order to improve the instrumentality of the use of flow optimisation law and flow analysis, it is necessary to clarify some concepts and definitions related to the flow in systems, clarify some formulations of the law and, in this regard, propose new methodological recommendations based on the above formulations and concepts.

1.3 Methods of solving the problem posed

The main methods of solving the problem were:

- A synthesis of experiences with stream and functional analysis and ZRTS analysis (in GEN3/Algorithm format),
- the method of classifying objects and concepts.

1.4 The results of the study carried out

1.4.1 The results of the work are:

- Introduction to the conceptual framework of flow analysis of stationary components related to flows
- Appropriate clarification of the provisions and wording of the law of optimisation of flows
- Identifying and describing the relationship between flow and functional analysis, considering flow analysis as a special case of functional analysis.
- Classification of flows by type
- Refine techniques and recommendations for improving flows in the system, taking into account their classification
- Three options for conducting a flow analysis are proposed, with recommended situations for which one or the other option should be used.

1.4.2 Practical relevance of the study

The use of summaries provides an opportunity to improve the effectiveness of the analysis, including

- identify new challenges that are not identified by the FA or PA applied separately,
- clarify flow-related tasks by locating them (tasks) more precisely

In addition, the methodology simplifies the search for directions for solving flow problems by classifying flows in more detail.

1.5 Key points to be defended

The functional approach in parametric form, adopted as the basis for the GEN3:ID methodology, is chosen as the methodological basis for the flow model. And, accordingly, the functional and flow modelling used in the GEN3:ID methodology is chosen as the prototype.

The theoretical basis for the analysis of the resulting models is the VAR system, also in the form of trends adopted in the GEN3:ID methodology.

The following changes have been made to the flow modelling and analysis part of this system:

1.5.1 Linking flows and other system components

- A definition of flow (not previously available) as a dynamic component of the system is introduced.
- In accordance with this, it is proposed to consider flow analysis as a specific special case of functional analysis. An appropriate refinement of the functional complete system model is proposed.
- Based on the model of a functionally complete system, 4 types of static components of a functional model are distinguished, necessarily accompanying any flow in the system:
  - Source,
  - Channel,
  - Receiver,
  - Control system,

  Similar to a functional model, each of these components (except the channel) may not be explicitly present or may be in a supersystem.
- Two main types of sources are identified and their main features discussed:
  - Source of potential,
  - Source of power.

  It is shown that consideration of these features should lead to a more appropriate choice of development (improvement) strategy for the system containing the flows.

- Two main types of management system are also identified:
  - A kind of "pump",
  - Kind of like a "valve".

  It has been shown that taking into account the type of management system chosen also enables a more deliberate choice of strategy for improving the flow and the system as a whole.
- A flow receiver is usually a working body, i.e. a key element of a functionally complete TS. Its analysis, more often than not, does not refer to the tasks of flow development, being an analysis of a higher system level. Therefore, it is not considered in this paper.
- It is shown that the flow channel is the most frequent element of flow improvement (along with the flow itself).
- Based on this separation of the static components associated with the flow, the flow improvement techniques proposed in the trend system are systematised and refined.
- In particular, it has been shown that the reduction in the conductivity of the harmful flow channel recommended by trends is an uncommon special case. Much more effective (and more common) is so-called "harmful flow channelisation", where a new harmful flow channel is formed in order to move the flow out of the system. The conductivity of such a channel, on the other hand, must be high.

1.5.2 Classification of flows

- As a special case of the components of a functional model, flows can be classified according to a number of specific characteristics. This classification allows for a more precise description of the characteristics of different flows. This makes it possible to offer additional guidance specific to different types of flows.
- A classification according to the following characteristics is proposed:
  - Separation of flows by functionality (useful, harmful and parasitic)
  - Separation of flows by source (primary or secondary),
  - Separation of flows in terms of 'horse-rider' (function or carrier),
  - Separation of streams into closed and open streams,
  - The division of flows into discrete, continuous and complex.
- In particular, a clearer definition has been proposed to distinguish between harmful and parasitic flows and thus offer different recommendations for them:
  - Harmful fluxes are fluxes that have a harmful function (and no main beneficial function) and are predetermined by the operating principle of the system. For example, carbon dioxide from combustion in internal combustion engines.
  - Parasitic flows are also flows that have a detrimental function (and no main useful function), but are NOT predetermined by the operating principle of the system. For example, nitrogen oxides and carbon monoxide in inadequate engine operation.

- For the different types and kinds of flows, their typical features are described according to the classification. Based on these features, additional techniques for their improvement are proposed.

1.5.3 Methodology for building a flow model

- Two main approaches to the formulation of TRIZ analysis and working methods have been identified. They can be conventionally called "step-by-step strategy" and "step-by-step algorithm".
- A step-by-step strategy describes the main directions, leaving enough room for imagination and creativity for the solver. The step-by-step algorithm involves following the prescribed guidelines literally or almost literally.
- Based on the proposed combination of functional and flow analysis, two methodologies have been developed and tested, corresponding to a strategy and an algorithm and combining the merits of both prototypes.
- For cases where flow analysis indicates that it is appropriate to focus on a particular static component, a methodology has been developed and tested for switching from flow analysis to functional analysis.

1.6 Personal contribution of the applicant

The author made a personal contribution to the study, developing the methodology and carrying out the study, analysing the results and developing methodological recommendations for flow analysis on the basis of these results.

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2 Flows and their relationship to other system components

A flow is the movement of material objects (matter and energy) or information in space in which individual moving elements move one after another, undergoing changes according to the same law (part of the flow can move in a supersystem, but the key is its presence and movement in the system in question).

Such a definition is not exhaustive for every conceivable case, but sufficient for practical work.

Essential to this definition is the presence of some number of elements of a discrete flow or the possibility of dividing a coherent flow into separate parts. A reciprocating pendulum or a rotating motor axle does not form a flow. A car on a track does not form a flow either, although a set of cars on a track does (and even if the set consists of a single element at a given time).

Another important characteristic of flow is movement in space. Water flowing in a tap or parts on a conveyor form streams. But when a tap is shut off or a conveyor belt is stopped, the flow stops (disappears), although all the elements of the flow remain in the system. That is, the flow is not just a set of elements, but a set of elements movement. Therefore, **flow is a dynamic component of the TS**, which is its main distinguishing feature. This is an important feature that distinguishes flow from other, "static" components of the TS: flow can "disappear" from the system without removing any parts from it.

2.1 Functionally complete TS and its relation to FA

The functional approach in TRIZ, though formulated rather late, goes back to the very origin of TRIZ. Namely, the law of completeness of system parts formulated by G. Altshuller as the first of the laws of technical development [e.g., in [1]]:

> A prerequisite for the fundamental viability of a technical system is the availability and minimum operability of the main parts of the system. Every technical system must include four main parts: engine, transmission, operating organ and control organ.

For the sake of generality, it makes sense to replace the terms engine and transmission in this formulation with energy source and energy converter.

The general diagram of a functionally complete TC is as follows

Include Diagram

Of course, real systems are usually more complex. This law establishes only the minimum components required to be functional.

A Functional Model (FM) is essentially such an extended schema. It should be understood that each function of the FM is performed by its own functionally complete minimachine. And the component that is mapped to the FM may include this entire machine in its composition, or it may use other components.

2.2 Functional and complete flow subsystem

In the case of a flow, it is not localised to a point. Therefore, a scheme of a functionally complete minimax operating on a flow should look somewhat different.

Include Diagram

More traditional Sankey diagrams for flow analysis (see e.g. [12])

Include Diagram

either completely ignore the component component or, at the very least, the functional (out-of-flow) links between components:

Include Diagram

In this paper, a flow is treated as a peculiar, but one component of a system. Also, components of its implementation such as source, channel and receiver are introduced into the description of the flow. Moreover, in fact, in a real analysis this is always the case, without which the analysis becomes no more than a pretty design.

Three important conclusions can thus be drawn:

1. **A flow is a component of the system and as such performs one or more functions. A flow function is defined in the same way as in FA, i.e. as the action of changing at least one parameter of the function object.**

2. **A flow in a system, similar to components in an FA, is always linked to a set of other components in such a way that together they form a virtual machine that provides the flow function.**

3. **Considering the flow with other functional (stationary) components allows for joint flow and functional analysis, which can markedly improve the quality of the analysis.**

The first conclusion is obvious to the point of triviality. But, unfortunately, it has not yet been properly verbalised. In particular, this is why functional analysis and flow analysis are still performed as two completely unrelated analyses.

The second conclusion is also clear. Moreover, in real projects, flow-related components and their properties are always taken into account too. But they are only considered in their relationship to the flow. But at the same time, they are also system components and usually have functional relationships that are considered in the FM. However, their functional relationship affects their interaction with the flow and vice versa. A simple example: the flow in a pipe causes corrosion of the components it washes. Hence, the "holding" function of the pipe walls starts to be performed inadequately. When PA and FA are used separately, this phenomenon can hardly be seen. In order to take this circumstance into account, one has to "work out" somehow in both types of analysis. To make it worse, the effect must be first seen and then included into the analysis. This causes the analysis efficiency to drop drastically.

After all, the analysis is done to see the effects of functional relationships, not just to list previously seen effects.

The third conclusion paves the way for the creation of a combined analysis methodology. Several options for such a methodology will be proposed below.

As a matter of fact, the very original scheme of a functionally complete machine already suggests such a possibility of unification. However, as noted above, this scheme goes back to the very foundations of theory. This confirms the validity of the proposed approach. Indeed:

Include Diagram

This diagram shows almost explicitly the energy flows from the source to the inverter and on to the actuator, and the information flows from the control system.

In principle, it would be possible to mark both the flows and the functional relationships directly on this diagram. But it should be understood that this diagram is the minimum diagram of a minimally functional machine. The FM of any real TS is always more complicated. Combining both flows and functional connections in one model will lead to unreasonable complication and oversaturation of the model, which will lead to its actual inoperability.

A close approach to this was suggested by A. Kashkarov in his 2009 Master Paper [11]. It is difficult to disagree with the thesis of the paper. But, unfortunately, the proposed technique of joint analysis is very labour-intensive, which reduces its applicability in projects

2.3 Flow channel as the main tool for flow management

Most often, flow optimisation comes from channel improvement and, to a much lesser extent, from source and consumer improvement.

This is due to the law of non-uniform development of system parts: both the consumer and the source are the working body (not necessarily the main one). Therefore, their development comes before the development of the channel (transmission in Altshuller's formulation, when he talked about energy flows in mechanical and electromechanical systems). Therefore, when the task of optimising flows comes up in a real working project, the optimisation of work tools has usually already been carried out and they are at the level of development that is available for a given system here and now. The task of improving flow sources and flow consumers (flow receptors) can be set, but almost always as a forward-looking task.

For example, in an internal combustion engine there is a flow of contaminants in the oil. As both a source and the "consumer" of this flow is the friction components (closed flow case). In addition to installing filters (channel control), it is possible to aim at reducing friction. For example, magnetic bearings completely or almost completely eliminate friction and thus drastically reduce contamination. But it must be understood that such a source conversion, if done, is done for other reasons (reducing friction in moving components is in itself a much more important task than reducing contamination in oil). Therefore:

- Such work is done for other reasons and has nothing to do with optimising oil flow,
- In any particular system, the existing level of friction is set either by technical possibilities or by economic and other constraints and is usually not manageable at this stage of system development.

- Nevertheless, this **flow** control option should be kept in mind (although it is most often not used)

Another example. On a production line, the scrap flow is a typical parasitic flow that must always be reduced. To improve the process, all three components are changed:

- The equipment where the defect occurs (source of flow),
- Rejects and rejects system (flow channel),
- Equipment of the next operation (consumer).

Of course, all three need to be improved. BUT:

It is reasonable for future projects to design equipment with a lower rejection rate (source) and a higher tolerance (consumer). In the non-TRIZ environment, this is formulated as a requirement for equipment designers to provide a larger range of input parameters and a smaller range of output parameters. Some other system improvement techniques, such as DFSS, have a similar objective. But it is reasonable to set such a goal for the equipment manufacturer, i.e. in this case a completely different system would be considered.

If, on the other hand, work is being done to improve a process that already uses the specified equipment, then the equipment parameters are a supersystem factor that is difficult to change (it makes no sense for a bread producer to propose solutions related to the development of a new oven as well as to the development of new wheat varieties). Therefore, in ongoing system improvement projects, rejection management (flow channel) is often the only option available.

2.4 Parametric description of the flows

The functional approach to describing systems also implies a parametric description. That is, a description of the main parameters of the functions in question.

Indeed, a function is an action that changes at least one parameter of an object. But in this way, a description of a function without specifying its parameters (the parameters of the specified action) becomes purely speculative and results in an empty functional model, only explaining what was known in advance. Not to mention that the refusal to parameterise leads to unworkable ideas, which at best entails a waste of time, and at worst up to the failure of the project.

In FM, however, a set of parameters can only be chosen for general engineering reasons. This is simply because FM deals with a whole host of TCs, differing in everything except perhaps the presence of the four mandatory components.

These flows are special cases of components and have certain common characteristics. Therefore, it is possible to classify according to these common characteristics and thus at least partially generalise the parameterisation procedure.

2.5 Types of sources

Streams can be divided into two broad types according to the type of source.

- The source that creates the force that moves the flow. Most often it is a continuous (coherent) flow.
- The source that creates (dispenses) the elements of a stream. Most often this is a discrete stream.

The first is, for example, an electric current (the source gives off an electric potential difference) and water/air flow (the source creates a pressure difference).

In the second case, it is, for example, the flow of parts on an assembly line (the source is the previous equipment that dispenses the parts) and the passenger flow on public transport (the source is the various kinds of rooms from which people go out into the street).

Clearly, these two types of flows need to be described and analysed differently.

2.5.1 Flux from a potential difference source

Such flows can be described by the formula

$$I = U \cdot \sigma(U) = U/R(U).$$

I is the magnitude of the flow, measured in flow elements per unit time (electric current in coulombs per second; air flow in cubic metres per hour, etc.)

U is the potential created by the source. I.e. – the force with which the source acts on the flux per unit of flux (Volt = 1 Newton per coulomb)

σ – The conductivity of a channel, i.e. the value that characterises the ability of a channel to transmit flux. It is measured in the amount of flux per unit potential.

R is the flow resistance of the channel, i.e. the value that characterises the braking of the flow by the channel.

Already from this formula three important conclusions are immediately apparent:

1. The necessity (relevance) of dividing a flow-related system into flow itself, channel and source: "Flow force" is a characteristic of the flow itself, potential difference is determined by the source, resistance by the channel.

   Note: Strictly speaking, the potential difference between the source and the consumer is determined by the potential of each of them. However, it is usually the source that determines this value.

2. The instrumentality of the approach. It is not always easy to identify which parameter in a given system is potential and which is resistance (unless, of course, we are talking about classical, "school" cases like a circuit of electric current). But it must be done: it is immediately clear which parameter needs to be worked on.

3. Since it is necessary to ensure a given "current" when working on flow, it is immediately clear that this can be done in two ways. In other words, two significantly different areas of further improvement are immediately outlined: working with "potential" and working with "resistance".

Linear and non-linear fluxes from a potential difference source

Fluxes from a potential difference source, in turn, can be divided into linear and non-linear. That is, into one where the resistance is independent of potential or current, and one where it is dependent.

It should be stated at the outset that there are no truly linear flows, there is always non-linearity. But within each given problem and within a given range of values, non-linearity can often be neglected. It is this kind of flow that is called linear.

The point of this division is that non-linearity means that not only the flow is dependent on the channel, but also the channel is dependent on the flow. That is, the channel in this case appears dynamised. This is the reason for many disadvantages. But also many opportunities.

Linear flow lacks this capability. And it is very often desirable to introduce such non-linearity. At the very least, it is a good additional possibility (see dynamisation law).

As an example, suffice it to recall that the advent of non-linear elements in electrical engineering has literally transformed the world. This is despite the fact that the share of electricity in total energy consumption has remained relatively modest, far below 50% [see e.g. [13]].

2.5.2 Element source flow

The flow from the element source is quite different from the previous one.

Such flow is characterised by source power W_s (source) and channel bandwidth W_c (channel).

The flow is described as follows:

If $W_s > W_c$, the amount of flow will be equal to W_c. I.e., there is as much flow through the channel elements as much as it can pass through. But the source output will either be jammed (traffic jam), or it will not operate at full capacity. In other words, there is an obvious a bottle-neck situation. But at the same time it turns out not to be described by speculative, but numerical.

If $W_s < W_c$, the amount of flow will be equal to W_s. This means that as many elements will flow through the channel as the source can deliver. But the channel will be underloaded (half-empty trains, a nearly dried-up stream). Here too, everything seems to be clear without any additional classification, but the situation turns out to be parametrized.

3 Flow types (classification)

3.1 Possibility and feasibility of classifying flows

One of the main advantages of traditional functional analysis – its universality – is achieved through a very high level of generalisation. Components are treated as a kind of universal black box (with, of course, the possibility to consider them in more detail if necessary). Functions often tend to be generalised to a narrow set of generalised functions. This is perfectly justified for a number of reasons, but it also leads to certain difficulties in further analysis: the recommendations of the methodology are forced to be generalised to no lesser level.

The recognition of a flow as a specific component of a system allows us to apply the signs of classification to them. As a matter of fact, this fact can already be seen in the work of Litvin and Lyubomirsky [6], where the primary classification of flows is made. However, it is possible to give a substantially more detailed classification of flows without violating generality. And, accordingly, considerably concretise the resulting recommendations.

Litvin's and Lubomirski's work divides streams in two ways.

- by nature (matter, energy and information flows)
- on the basis of functionality (useful, harmful and parasitic flows).

The first indication is unmistakable. Although the duality of many fluxes does occasionally come up. For example, an electrical signal is a flow of electrons electronic circuitry (matter), electrical energy or information? Usually the question is decided according to the task at hand. If the task is interested in the information component – the flow is considered as a signal, if the board is interested in heating – as energy, if the physical principles of operation are analysed – as electrons (holes, ions, etc.). But in fact, there are three different fluxes closely related to each other. And – not necessarily with unambiguous connection. This ambiguity of connection of three kinds of flows opens additional possibilities for development (perfection) of systems. Not taking this factor into account does not make the analysis inherently wrong, but it narrows the scope for problem setting and subsequent problem solving.

It follows from this that a more detailed classification of flows as compared to components

B) is possible

A) is appropriate.

3.2 Separation of flows by functionality

- **Useful streams in a system are streams intended to perform a useful function in the system** (regardless of the quality of performance),
- **Harmful flows in the system are flows NOT intended but unavoidable** according to the operating principle or coming into the system from outside (external),
- **Parasitic flows – flows that are not required by the chosen operating principle** and that perform a harmful function or impair the performance of a useful function, arising from design imperfections.

It may seem that the mere recognition of flows as components of a system makes it meaningless to divide them into useful and harmful components. Indeed, it is not common in functional analysis to divide components into useful and harmful. If a flow whose main function is harmful is called harmful, it is clear that the designers did not introduce this flow on purpose. This flow either arose in the process of functioning or came from a supersystem. In principle, harmful stationary components can be formulated: components that have arisen during the functioning of the TS or components of the supersystem that perform harmful functions. For example, pollutants of all kinds. It is clear that in FA the occurrence of such a component unambiguously triggers the elimination task and therefore no additional classification is needed.

However, this is not the case with a flow. Above, a flow has been recognised as a "virtual" component which can arise and disappear as a result of interaction with other components. Harmful or parasitic flow can result from component interactions (in the case of a parasitic flow, a useful but inadequately performed interaction, in the case of a harmful flow, a harmful interaction). In addition, a flow travels through the system and often there may be a situation where a flow performs the useful function for which it was created, in one place in the system, and then turns into a harmful one. Finally, flow can enter the system from outside the system.

Thus:

- **Harmful flows in the system objectively exist.**
- **The different ways in which they are formed also allow for an additional classification to be applied**.

Just as in FA, one can set a goal of unconditional elimination of harmful fluxes. But harmful flow (as well as 'harmful component') is an intractable consequence of the chosen operating principle. Therefore, a more detailed classification of fluxes makes a lot of sense in order to choose the right way to minimise the harmful flux or its detrimental effect.

3.2.1 Typical techniques for optimising beneficial and minimising harmful flows, taking into account the main components

Chapter 5.1.4. of [6] lists just over forty "subtrends" of flow optimisation. In essence, this list is a fairly comprehensive list of techniques to address the weaknesses identified in the flow analysis. These techniques are also described in some detail and illustrated with examples. A detailed description is not required in this paper. Some features, determined by the identification of "stationary" components associated with the flow, as well as the structuring of flows, will be given later in the chapters "Harmful flows. Work with flows depending on classification" and "Useful flows. Workflows depending on classification".

In a sense, the list is analogous to Altshuller's 40 techniques. The list is almost completely unstructured, apart from dividing streams into useful and harmful ones.

When stationary components are matched to each flow, it is possible to make more precise recommendations on the application of these techniques.

Include two Diagrama

This division is superficially similar to the division of Altshuller's 40 techniques made by ARIZ-91 (St. Petersburg) [14], although it differs in the genesis of the division.

A detailed description of the individual techniques is given in sufficient detail in the work of Litvin and Lyubomirsky and requires no further justification. At the same time, the proposed division allows:

- Increase the efficiency of the analytical and decision-making procedures by reducing the overshooting of options.

- Focus the identified weaknesses and therefore the objectives on the specific components of the system under analysis

In addition, it is possible to select (or rank) different solutions depending on the conditions of the project:

Include two Diagrams

This is made possible by the law of unequal development of the parts of the system [6], according to which the first in the system is the working body, followed by the transmission and then the source. In this case, the flow receptor is usually the working body (a component of a higher functional rank) and, by virtue of the law of non-uniformity development of the parts of the system, develops before the other components. So by the time The flow optimisation task is often already developed to the point where which it is possible to do in the "here and now". The source of the flow, the primary shaping it parameters, is most often a component of a lower functional rank. But on the other hand, it is more often a supersystem component and its improvement may also be difficult or impractical for each given task. The channel, on the other hand, is an auxiliary component whose only useful function (at least in the context of flow analysis) is to direct the flow. Therefore, its improvement can proceed painlessly for the functioning of the system as a whole. At the same time, the channel largely determines the efficiency of the flow.

As a result, in order to improve a system quickly, albeit in a shallow way (which is often the case), one must first try to improve the channel, then the source (if permitted by the design constraints) and only at the very end the working body (the receiver). If, however, the requirements are set for in-depth if the system is to be improved, first the possibilities of improving the working body (up to and including changing the principle of operation) should be analysed, and then the components that ensure its operation. As a matter of fact, a similar recommendation exists in FA, where it is expressed in the form of ranking the functions according to their functional importance (see, e.g., [15]).

Parasitic flows are, by definition, flows that are *not unavoidable* in principle, but that either perform a harmful function or impair the adequate performance of a useful function. Therefore, the first recommendation is to eliminate such flows completely. If this fails, then the parasitic flow should be dealt with according to the same rules as for harmful flows.

3.3 Classification of flows according to other characteristics

In addition to the division of flows by their nature (substance, energy, information) and functionality (useful, harmful, parasitic), it is also advisable to divide flows by some other characteristics. The classification proposed in this paper is not the only possible, but it seems optimal: distinguishing flows by these characteristics most often leads to significantly different conclusions and recommendations:

- **Separation of flows by source (primary or secondary)**,
- **Separation of flows in terms of 'horse-rider' (function or carrier)**,
- **Separation of streams into closed and open streams**,

- **The division of flows into discrete, continuous and complex**.

See below for a more detailed description.

In situ, depending on the task at hand, other classification attributes may also be used. Such additional characteristics may include, for example:

- system rank (main or auxiliary flow) – depending on what function the flow performs in the system,
- localised or distributed,
- stationary or non-equilibrium flow,
- easily or hardly manageable (difficult to control) flow,
- etc. – but this kind of classification should be introduced ad hoc.

The main flow is the flow that directly performs the main function of the system or that provides it to the corresponding component. An auxiliary flow, similar to an auxiliary function in FA, is defined as a flow which provides that function to the main flow, but which has no independent significance.

A localised flow is one that flows in a channel with clearly defined boundaries. Distributed flow is flowing in a channel with unspecified boundaries or one for which the channel is the entire volume of the system.

A stationary flow is a flow with constant parameters over time. A non-equilibrium flow is a flow whose parameters change over time.

Of course, whenever there is a real analysis in a project, the industry classification must also be taken into account: direct or alternating current in electrical engineering, sound or ultrasound in acoustics, group or individual processing in technology, etc.

3.3.1 Separation of flows by source (primary or secondary)

The primary flow is the flow coming from the supersystem; the secondary flow is the flow generated within the system.

It is clear that these flows must be handled according to different rules, which the current version of the methodology does not take into account.

For example, a primary utility stream is often unambiguously defined by its parameters and it is virtually impossible to modify it. In an extreme case, it is possible to transform the flow, i.e. to form a new flow, already secondary, from the original primary flow. It is clear that it is an extreme case as it knowingly complicates the system. For example, compression of atmospheric air in an internal combustion engine.

In this case, the concept of secondary useful flow refers directly to the properties of the source. This means that even the separation of flows in this way helps to identify immediately the component of the system to be improved.

Similarly with noxious flows. The primary detrimental flow must (preferably) be directly inhibited at the inlet. At the same time, the secondary harmful flow is, by definition, shaped by the operating principle and cannot be prevented without changing the operating principle.

Thus, just a proper classification on this basis can quickly point the way towards solutions.

3.3.2 Dividing flows by function or medium

Many flows in the system have the only useful function of carrying another flow. For example, for substance flows, these are group container flows in shop floor or transport logistics. Their only purpose is to carry some other flow, which actually performs a useful function.

Accordingly:

- **A carrier stream is a stream intended (performing the function of) transporting some other stream.**
- **A function stream is a stream that actually performs a function other than that of the carrier stream.**

A phenomenon very common when considering matter flows. Energy flows almost always and information flows simply always require the involvement of a carrier flow.

In the current version of the methodology, there is only one hint of such a division:

> The use of one flow as a carrier of a second flow. A regularity in the development of technical systems, consisting in the transition from independent transmission of heterogeneous flows to the carriage of one flow by another [6].

But here we are talking about the possibility (and it is emphasised that sometimes) of giving some kind of flow a carrier function, nothing more. Meanwhile, the phenomenon is extremely widespread in technology.

The presence of a useful flow of matter in the system almost always guarantees the existence of at least two other useful flows supplied by the carrier.

For example:

It would seem that what kind of carrier flux acts in a flat on the water that flows from the tap? But for the water to flow, there has to be a controlling effect, which requires a flow of information. That flow needs a carrier. And it also needs energy to turn off the tap. This energy also has its own medium. It is not always the case that these flows need to be considered in PA and in the solution of a particular problem. But what is important is that they are there. For example, the principle of medium substitutability (see below) has been applied to the design of taps that open when hands are placed on them.

Hydrocarbon fuels are often carriers of various types of additives (and the resulting mixture is a carrier of chemical energy)

In batch processingq, the workpieces (semi-finished products) are arranged in cassettes (boxes, trays, etc.)

Tara is a typical flow carrier.

It has already been mentioned that water is the carrier of the auxiliary flow of salts in the preparation of all kinds of brines (and the brines themselves are often used as carriers of the "cold" flow).

The operator's labour cost stream (a specific, but quite real auxiliary useful stream costing the employer real money) is a typical carrier stream Useful streams (functions) for production are streams of decisions made and actions taken. This creates a harmful (from the employer's point of view) secondary 'labour cost' flow (not always mandatory and very often – inadequate...).

Etc.

Thus, the separation of flows into medium and function is essential and deserves to be analysed in its own right.

3.3.3 Dividing flows into closed and open

- **Closed threads are defined as threads that are returned to their source for reuse.**
- **Open threads are either those that are discarded into the supersystem after use, or those that are dissipated altogether.**

The current version of the methodology [9] considers only open flows. This approach is possible for two reasons:

- Closed-circuit flows are used much less frequently. Mainly found as carrier flows.
- They can be regarded as open because the closed stream returns to the source with modified properties, requires some kind of processing to reuse and can therefore be regarded as two different streams with different parameters (before and after conversion).

  Nevertheless, closed and open streams have significantly different properties and can be improved by different techniques.

3.3.4 Separation of flows by connectivity

The flows in the system are divided into:

- Discrete (multi-component)
- Bound (solid)
- Comprehensive

The principle of separation is clear. For example, flows of parts on an assembly line or cars on a highway are discrete flows. A flow consists of complete units – the elements of the flow. Any such element can be removed from the flow and treated as an independent component of the system. The flow is formed not so much by these elements, but by their movement according to the same law. The simplest attribute: the units are pieces per unit of time.

A variety of liquid and gas flows are examples of continuous flows. It is usually not possible (or practical) to isolate a single element and consider it on its own. The static component here can be considered to be the totality of the material being moved (in the case of a flow of matter). Characteristic: For a static component, the unit of measure is kilograms, litres, etc.; for a flow, it is kg/sec, litres/min, etc.

Energy flows also refer to continuous flows.

Complex flows combine features of both of the previous options.

For example, the rock flow in a rock avalanche consists of individual rocks, each of which can also be considered as a separate component of the avalanche – it is a typical discrete flow. In contrast, debris flow consists of a mixture of two or three different flows (water flow – continuous; rock flow – discrete; clay slurry flow – continuous and complex within itself). Depending on the problem to be solved, it may be necessary to consider these flows separately, but in science the mudflow is considered as a single complex flow (see, for example, [16]).

Another example: the flow of information in digital form consists of individual bytes, in textual form of words. Both bytes and words can be treated as separate components and analysed separately. When put together, they acquire an additional quality.

The sign of complex flow: the unit of measurement is the number of different discrete elements.

However, in each situation, a complex flow should be considered either discrete or continuous, depending on the problem. However, in any given situation, a complex flow should be considered either discrete or continuous, depending on the problem.

It is clear that discrete and continuous flows have slightly different properties. The main difference lies in the way it is generated, i.e. in the source of the flow. For Continuous flows are characterised by a "source of potential", discrete flows by "current source". The differences will be discussed in a later chapter. After the output from the source, both types of flow behave closely. For example, the flow of cars on a track of limited width can be described by equations, surprisingly resembling Ohm's, Kirchhoff's and Bernoulli's laws.

3.4 Example of classification

It is convenient to consider the internal combustion engine as an example of the proposed classification.

- Separation of "source/channel/stream/operating body":

  The flows are petrol, air, exhaust, cooling air, etc. The channels are the petrol supply pipe, air supply pipe, cooling air pipe, exhaust pipe, etc. The source of the exhaust gas is the combustion chamber. The cooling air product is the heat exchanger, etc.

- The main useful flows are (based on the ICE principle)
  - the flow of petrol,
  - the air flow into the engine.
- Auxiliary useful streams are:
  - the flow of all sorts of additives in petrol, the flow of oil in the engine,
  - the flow of coolant.
- The external useful streams are both the main streams mentioned (petrol and oxidiser) and the additive stream in the petrol.

- The internal usable flows are: oil flow, combustion product flow in the cylinder, part of the heat flow, coolant flow.
- External harmful flows are various types of contaminants in the petrol and air, and air nitrogen.
- Secondary harmful flows:
  - The flow of carbon dioxide and vapour produced by the combustion of petrol.
- Parasitic flows:
  - Nitrogen oxides and carbon monoxide flux
  - Flow of petrol additives decomposition products
  - Contaminant flow in the oil
- The "horse-rider" division:
  - Cooling air (or liquid) is the typical carrier ("horse")
  - The flow of heat (cold) is a typical feature ('rider'), which is actually what makes it easy to change the carrier.
  - The gasoline additive flow is a functional flow in relation to the gasoline flow. The gasoline itself is the carrier of the additive flow (being at the same time an important functional flow!)
- Closed-loop flows: engine oil flow, coolant flow, contaminant flow in the oil.

Of course, as always, it is necessary to look at the system not in general, but in relation to the purpose of the project. Therefore, depending on the problem to be solved, other options are possible: the main useful flow is air oxygen, while nitrogen and other gases in the air are an external harmful flow. The gasoline and additive flux can be considered as a single flux, and the cooling agent flux as an auxiliary useful flux, etc.

Of course, this classification is much more complex than in the current version. Therefore, **the level of detail should be chosen to be at least sufficient for the objectives of each specific project**.

At the same time, such classification still arises in any detailed flow analysis. Without which, it turns from situation analysis into drawing more or less pretty pictures, which has to do with presentation of results rather than obtaining them (although, of course, a competent and accurate presentation of TRIZ analysis results is often important in a project in its own right). But it is clear that different flows require different approaches to improvement (optimization, efficiency, etc) of the system. But since this is the case, it is also useful to distinguish between different types of flows.

The example given of flows in the ICE is a good example of clear separation. Of course, a huge number of combinations and details are possible. For example, the joule heat flux in an incandescent lamp – is it a secondary harmful flux or an auxiliary useful or even a primary useful flux? Of course, the answer depends entirely on the objective of the project. At the same time, the same joule heat flux in an LED is known to be harmful.

In any case, for each specific project, this classification of flows is very useful for the subsequent resolution of identified deficiencies. The author has repeatedly applied this classification and has always obtained a satisfactory result. Often it is sufficient to simply provide the classification designations in a standard flow analysis table.

For example:

- Petrol in an internal combustion engine is
  - Main
  - useful
  - external
  - open
  - a flux-functional (although in relation to additives it is a carrier).
- Oil contamination arising from friction of moving parts is
  - harmful
  - secondary
  - closed
  - functionality.

etc.

4 Harmful flows. Techniques for dealing with fluxes depending on classification

4.1 A slight terminological digression

In their paper by Litvin and Lyubomirsky (and this is the only paper where the law of flow optimization is considered in sufficient detail), the authors use the term "subtrends". This refers to the most frequent directions of development of successfully developing TC. It recommends following these sub-trends.

This paper uses the term 'techniques'. Techniques refer to recommendations to engineers, the application of which often leads to successful development of the TC.

Still, trends (and sub-trends) should indicate some kind of line of development from one described point to at least one more. Therefore, for example, the *sub-trend "The pattern of development of technical systems consisting in the transition from a flow containing areas of resistance significantly greater than the flow resistance of the path, to a flow free of such areas"* looks a little unsightly. At the same time, the *recommendation to "get rid of areas of high flow resistance" looks both shorter and clearer.*

Of course, it should be understood that the work of Litvin and Lyubomirsky focuses specifically on describing trends, so wording in the style of trends is appropriate to preserve the stylistic unity of the text. The situation is entirely analogous to the difference between the laws of development in general and the 40 techniques of resolving contradictions.

Of course, at the level of philosophical generalisation there is a significant difference. However, for practical application, this difference does not seem to be significant.

4.2 Reducing the conductivity of external harmful flows at the inlet to the system (even to the point of forming an impenetrable barrier to these flows)

External flows are supersystem flows and are therefore hardly manageable within each given project. The source of the external harmful flows from the point of view of the system in question is the input to the system. So it is most often only possible to control the point of entry of the flow into the system.

For example:

- Filters installed at the inlet to the ICE are a typical example of reducing the conductivity of a harmful flow *input* channel.
- Another example is the various ways of restricting heavy vehicles from entering city centres.

This approach is generally applied very widely, but there is a serious problem: a channel for external harmful flow is very often (more often than not) a channel for some useful flow. If there is a draught in the room, the natural inclination is to close the window. But immediately the flow of fresh air is stopped! Therefore, **the presence of an external harmful flow (even if stopped!) at the inlet to the system is an indicator that there may be a problem.** Same example with filters: Filters not only stop the flow of pollutants, but also inhibit the beneficial flow. On the other hand, having seen filters at the inlets of a completely unfamiliar technical system, an engineer can draw at least three conclusions straight away, without any analysis, when they first become acquainted with the system:

- There is a harmful flow at the inlet
- The rest of this flow is inside the system
- The conductivity of the useful flow channel is reduced.

Thus, the additional classification of flows and flow-related system components is in itself quite an instrumental technique. And what's more, a technical contradiction of the "there must be a filter, but there must not be a filter" kind can be immediately formulated.

4.3 Management of the formation of secondary harmful flows (reduction of specific flow characteristics)

Internal flow arises, by definition, as a result of a working body (considered in this case as the source of the harmful flow) performing some useful function (or some component performing an auxiliary function).

At first glance, it would seem that it is the improvement of the working body that should prove to be the main measure to combat such flows. But this is not the case. By virtue of the definition above, secondary detrimental flow is inevitable when performing a useful function. It can only be completely eliminated by switching to a new operating principle. It is usually possible to reduce the damaging parameters of this flux. But due to the law of uneven development of the system parts, the resources of the working body development are usually already used at the previous stages of development of the system as a whole. Therefore, when a project concerns a system that has already been on the market for some time (and this applies to most real-world projects) – the operating body is often difficult to improve.

For example, two powerful secondary pollutant flows are generated in an internal combustion engine: heat, which must be diverted from the cylinders on the third branch of the Carnot cycle and the products combustion (water vapour and carbon dioxide). Both of these flows can only be avoided by the principle of operation is abandoned (e.g. by switching to an electric motor), but It's the internal combustion engine that's being analysed!

The amount of carbon dioxide can be reduced by switching to gas, then alcohol and finally hydrogen. BUT:

Firstly, not to eliminate, but only to reduce somewhat (the hydrogen engine, as well as hydrogen power in general, is usually seen as a new principle of action; most often, a fuel cell, which is certainly a different principle of action, is considered at once); secondly, this trend has very serious supersystem limitations, little by little implemented, but, most importantly, from completely different considerations.

Therefore, the task of changing the operating principle for the sake of reducing the secondary detrimental flows in the system – within the framework of solving a local problem – is usually not possible. And it is precisely such tasks that form the basis of the entire array of our projects. Changing the principle of action implies the actual transition to the 1st stage of development of a new S-curve. And at this stage, TRIZ is usually dispensed with.

4.4 Managing the formation of parasitic flows

Parasitic flows in a system are very similar to secondary harmful flows, but differ from them in that, by definition, their occurrence is not determined by the operating principle of the system. Therefore, an important sub-trend of system development emerges: minimisation of parasitic flows (up to complete elimination). When parasitic flows are identified, it is their minimisation that is the first area of improvement.

For example:

Carbon monoxide associated with incomplete combustion is a typical parasitic flux. The first (best) solution should be a solution aimed at complete combustion (prevention of parasitic flux).

An important special case of parasitic flow is all kinds of useful flow leaks. The natural inclination is to eliminate and/or prevent these leaks (mentioned here simply for completeness, although in principle the solution is clear: if a tap is leaking, it simply needs to be repaired).

4.4.1 Parasitic flow formation as a sign of contradiction

Except for the simplest (though practically important) case of leakage, the presence of parasitic flow in a system is always a sign of contradiction: parasitic flow is by definition not an inevitable consequence of the operating principle. That is, some properties of the system on the one hand must be realised (the need for which is determined by the need to perform some useful functions), but at the same time, must be changed in order to prevent the occurrence of parasitic flow.

For example, in ICE the typical parasitic flux is the flux of nitrogen oxides in the combustion products. The contradiction looks like " the combustion temperature must be high to ensure a high ICE efficiency, but at the same time low to prevent nitrogen oxides". OR: " there must be nitrogen in the oxidizer so that the cheapest and most readily available of all oxidizers air can be used, but there must be no nitrogen so that nitrogen oxides do not occur".

What is also important is that not only is a contradiction easily detected in this way (one of the most important goals of analysis in TRIZ), but it is localised in the component of the system that acts as the source of the flow (i.e., the operational area and operational time are automatically determined immediately).

This example raises another very interesting collision: at the same operating time and in the same operating zone, another parasitic flow – carbon monoxide – occurs. The contradiction here looks something like this: "the amount of oxygen must be excessive to prevent incomplete combustion of hydrocarbons. But the amount of oxygen must be insufficient to prevent oxidation of nitrogen (and also prevent a number of other problems)".

I.e., two different contradictions have to be solved, converging strictly at the same time in the same place: if there is a lot of oxygen, nitrogen oxides arise; if there is little oxygen, carbon monoxide arises.

4.5 Harmful flow channel management within the system

4.5.1 Ducting of harmful flows – increasing the conductivity of ducts for the removal of harmful flows moving within the system

The first way to manage harmful flows is by sewerage (forming a channel to remove the flow from the system).

In the current prototype methodology, the first solution is to reduce the conductivity of the harmful flux channel.

Sewerage is completely at odds with the current flow analysis methodology, but the method is very important, effective and widely used in practice:

- In the example of an internal combustion engine, the heat from the cylinders on the third branch of the Carnot cycle needs to be removed as quickly as possible. Similarly, the combustion gases from the cylinders need to be removed, not retained at all.
- In industrial production, returnable waste carries the cost of all the processing steps that the raw material has undergone. Therefore, rejecting such waste as early and efficiently as possible (i.e. – increasing the conductivity of these waste channels, e.g. by reducing the channel length) is a very cost-effective solution.

- Fans and heat sinks are measures to increase the conductivity of harmful heat flow in electronic appliances and generally in all electrical machines.
- In the chemical industry, rapid removal (i.e. using a high conductivity channel) of unused reaction products dramatically increases the beneficial effect and/or speed of the main reaction (and what happens when the draft in the chimney drops – you know).

So the thesis that the harmful flow present in the system should always be inhibited seems categorically wrong.

Where it is not possible to remove the harmful flow from the system quickly, it is necessary to reduce its harmful effects.

Note: it must be remembered that in the vast majority of cases of material or energy flow, it will still be taken out of the system simply by virtue of the laws of conservation of energy and matter. The exception may be single-use systems that accumulate their own waste. Therefore, it is a matter of the harmful flux not being able to be discharged outside the system in precisely the quickest and most manageable way possible.

Under these conditions, it is indeed usually necessary to inhibit the harmful flow. In this case, either another channel will form, which will take the flow out of the system along a less harmful path, or a dissipation of the flow will occur. In this case, the sub-trend described by Litvin and Lyubomirsky applies: "Reducing the conductivity of the harmful flow channel".

There are quite a few techniques for implementing a sub-trend, and they are described in detail in private technical areas. They basically boil down to the following:

4.5.2 Reducing channel conductivity

A fairly straightforward solution. If it is necessary to reduce the intensity of any flow, it is reasonable to reduce the conductivity of the channel. In turn, the conductivity of the channel can be reduced by reducing the conductivity of the existing channel links.

In particular, are widely used:

- Increasing the length of individual canal links
- Reduced specific conductivity of individual channel links.

ICE one of the secondary harmful flows is the flow of gases through the seals in the piston group (crankcase gases). Typical parasitic flow, but it has already been noted above that once the harmful flows have penetrated/formed within the system, the difference becomes purely academic. Crankcase gas flow on the one hand is not predetermined by the operating principle of the internal combustion engine. On the other hand, complete elimination seems to be impossible. The main way to reduce such flows is to improve sealing, reduce abrasion, etc. – typical methods of reducing channel conductivity. It is significant that in modern vehicles forced draining of such gases is applied as well [17].

4.5.3 Introducing "bottle necks" into the channel

A bottle-neck is an extra link in a channel with a deliberately lower conductivity.

This definition distinguishes this technique from direct reduction of the conductivity of existing channel links. The solution is very often used in engineering.

One of the most typical examples is a filter: where a harmful flow goes through the same channel as a useful flow, the filter separates the two flows and inhibits one of them (the harmful one). Another typical example of a bottle-neck is a valve which closes a channel (partially or completely) and thereby reduces its conductivity in a controlled manner (but for all kinds of flows coming from that channel).

For example, during the operation of an internal combustion engine, a specific flow is generated, such as the flow of contaminants in the oil. Quickly and reliably filtering out and dumping these contaminants is technically possible, but quite expensive. Therefore a filter is used which simply inhibits said harmful flow. The flow is only occasionally removed from the system when replacing the filter.

Other examples of filters and valves in various sectors of technology can easily be found to suit every engineer's taste in sufficient quantities and according to their specialisation.

4.5.4 Introducing "stagnation zones" into the channel

In general, the introduction of stagnation zones is not an independent technique. Any reduction in intensity or flow velocity at any link in the canal, whether reducing the conductivity of an existing link or putting in an additional link, creates a stagnation zone (by definition).

A typical way of creating stagnation zones is to create a bottle neck in the flow path. The concept of a 'stagnation zone' as a separate technique makes sense because the appearance of such zones quite often allows the harmful flow to be dealt with more effectively. For example, it is possible to form a channel for draining or processing the harmful substance (energy) from the stagnation zone.

4.5.5 Introducing 'stagnation zones' into the combined flow channel. Stream filtration

Very often a bottle neck creates different resistances for the different elements of the combined flow. Such a selective bottle-neck is called a filter and allows for separation, partially or completely, of the flow elements.

This separation can be used in different ways:

- Separation of substances proper
- Increased concentration of the element with lower conductivity in the stagnation zone
- Forming a channel for concentrated substance drainage from the stagnation zone
- etc.

In an internal combustion engine, for example, the filter is not only a bottle-neck for all sorts of contaminants, but also a concentrator for these contaminants. This makes it relatively easy to remove contaminants by simply changing the filter. The same fact makes it possible to set a target for contaminant drainage – for example, by introducing self-cleaning filters.

Another example: sumps in water treatment systems are typical stagnation zones. Due to the higher concentration of contaminants, their treatment (including chemical treatment) is much cheaper and more effective.

4.5.6 Disposal of secondary harmful and parasitic flows

This is also a commonly used method. In essence, it is a direct application of the 22nd technique of eliminating contradictions "to turn harm into benefit".

For a very long time, factories have been collecting all sorts of waste for recycling (scrap metal and waste paper collection are well known, but the list could go on and on).

The essence of the method is precisely the inhibition of harmful flow within the system, which outwardly corresponds to the existing version of the law. However, the next step is taken – the flow is stopped completely, accumulated in some collector and then still taken out of the system through a new specially organised channel. That is, it is the same sewerage of the harmful flow, just the flow is transferred to a new channel while suppressing the pre-existing one.

Disposal should be applied when the elimination of these streams is difficult or impractical (e.g. economically).

4.6 Use of secondary flow within the system

A special case of the previous one. The method is used rather rarely precisely because the secondary harmful flow arises as waste associated with the operating principle, i.e. as an unusable flow.

For example, it is quite common to try to use secondary heat. The result is not always there, but when it is, the effect is quite good.

Perhaps the only example in the ICE is the use of waste heat from the engine to heat the carburettor (but outside the ICE as such).

It is much more common to attempt to use the secondary flows in a nearby supersystem. The option again brings us back to the intake of sewer secondary flows into the supersystem, but with subsequent use there.

For example, secondary heat from the internal combustion engine is used to heat the vehicle cabin.

So it should be borne in mind that such use is always aimed at some kind of auxiliary or supplementary function.

A possible use of this sub-trend: a target could be set for the use of waste heat within the internal combustion engine. Where in an internal combustion engine is such a resource as heat needed? For example, there are known attempts to heat petrol and air with this heat just before it enters the combustion chamber. Or, for example, to heat the neighbouring cylinder on the return stroke. Of course, this is just a problem statement, which still needs to be solved (and quite possibly abandoned due to inefficiency), but if the problem is not set, there will be no solution. At the very least, a functional analysis of the system must be carried out in order to solve it accurately.

In rocket engines, the fuel passes first through the winding on the nozzle and then, once hot, goes to the nozzles.

Using production scraps as returnable waste

Returnable waste in production refers to those types of rejects that can be returned to the same production within the same or the next production cycle (not to be confused with recycled waste – waste used elsewhere for other purposes). Generally, these are rejects that have not yet gone through the full production cycle but have been screened out in earlier stages. For example:

- When making various dough pieces (and in general any mixture), some pieces are irregularly shaped and are removed from the further process. These pieces are sent back to the mixer and re-formed as part of a new batch of dough. The economics of this are quite clear.

But keep in mind that this part of the semi-finished product goes through some operations twice, i.e., the cost of the final product will be higher than possible.

In this case, all three methods (sub-trends) described above apply and exactly in the sequence proposed:

- The first thing to do is to take measures to reduce scrap (improving the subsystem where scrap occurs – the task moves out of flow analysis and into the realm of functional analysis).
- Next, measures must be taken to dispose of parasitic waste – i.e. just using rejects as returns. While such a solution is trivial, it is far from always dealt with, so there are very often good resources here.
- Not every marriage manages to be used as a return, of course. But sometimes it is possible to use it in some other way. Apart from the aforementioned collection of recyclables, there are the most unexpected solutions.

For example, Svetlana (St. Petersburg) used discarded vacuum bulb flasks to make shot glasses and glasses. Moreover, the materials sprayed in the lamps as adsorbers were also sometimes of poor quality. However, decorativeness of such sprayed films did not suffer and those shot glasses were decorated exactly from such rejected ingots. The funny thing is that the production of these shot glasses continued even after the closure of the main lamp production – but this is already a question of the fourth stage of the development of the system.

4.7 Harmful flow reconciliation with other parameters

An extremely important point, which in the current version is accounted for by one sub-trend among others and is not specifically stated in any way:

> "Reducing the specific characteristics of harmful flow"

Already the simple division (classification) of components into source, channel and receiver clarifies this trend:

As a technical system develops, the sources of secondary harmful flows change so that the specific flow parameters decrease[1].

In doing so, the task is immediately localised to the source.

For example, the ratio of carbon dioxide to water in the exhaust gases changes towards an increase in the percentage of water in the series 'petrol – gas – alcohol'.

But it should also be noted that this sub-trend is one of the weakest and seldom realised. Secondary detrimental flow is predetermined by the principle of action. Therefore, the parameters of this flow are also difficult to change. However, by selecting (matching) the parameters, it can be significantly weakened.

Furthermore, only secondary harmful flows may be involved. Primary flows are set by the supersystem. While useful flows can often be regulated in some way (we can choose the type of petrol we want at the petrol station), harmful flows are hardly adjustable (we cannot choose the composition of air supplied to the internal combustion engine).

It was shown above that formulating such a sub-trend for a channel is virtually impossible: neither a decrease in the conductivity of the channel nor an increase in it is a trend in the conventional sense of the word – i.e. a major line of development.

All the more so, reducing the receptor's susceptibility to the harmful flow cannot be recommended: this would be a typical remedial technique, whereas the main line of development should certainly be to attenuate the harmful effect of the flow itself.

5 Useful flows. Techniques for working with flows depending on classification

5.1 Harmonisation as a principle for improving utility flows

At first glance, it would seem that actions on beneficial flows should be inverse (symmetrical) to actions on harmful flows. However, this is not the case.

While harmful fluxes must in any case be either removed or attenuated, useful fluxes are by no means always subject to amplification. As a rule, there is a certain optimum set of parameters, exceeding which is at least unproductive, and often harmful. It is therefore more appropriate to apply the concept of redundancy – insufficiency, i.e. inadequate performance of the function. And consider it a task to ensure that the function is adequately performed.

A number of examples supporting this fact can easily be continued for any field of technology:

- Useful fuel flow in an internal combustion engine. If the conductivity of this flow channel is increased, additional fuel flow into the combustion chambers will result in incomplete combustion, which in turn will lead to a number of serious problems.

[1]The specific parameters (characteristics) of flux are the value of an absolute parameter referred to a unit of flux. For example, current density compared to current strength, substance density compared to mass, etc. Clarification about specific parameters is important, because most often it is its specific characteristics that determine the harmful properties of the flow.

- Useful flow of hot water or steam in the heat exchanger jacket. Increasing the conductivity of this duct will remove heat from the system, although we need the opposite.
- Useful Joule heat flux in an incandescent lamp when the conductivity of the conductor increases will change its rating, and above a certain limit will simply cause the lamp to burn out.
- Useful flow of semi-finished product to some kind of actuator (to the flow consumer) if the conductivity rises above a certain limit, the consumer will become overstocked and/or a buffer store will need to be introduced.
- Etc.

Of course, the current version of the flow law does not talk about enhancing the useful flow, but about enhancing its usefulness, however:

- in this formulation, the law becomes completely non-instrumental. It may as well be formulated as a requirement for any other component or parameter of the system. Strictly speaking, the trend will be exactly that, but knowing it will not help the engineer solving the particular problem,
- The techniques (sub-trends) presented in the work of Litvin and Lyubomirski mainly focus on strengthening the main flow parameters. This is generally wrong (and can be seen from the above examples, which can easily be continued).

Therefore, the main method of improving the use of useful flows is to harmonise the flow parameters with other system parameters.

Thus, the law of flow optimisation in terms of useful flows is a sub-trend of the law of increasing coherence.

This should not be surprising: The VTRS is not just a list of trends, but a system of trends, so such mutual overlaps are inevitable and objective.

5.2 Matching main utility flows by intensity (flow)

The law of increasing coherence is one of the most instrumental in the system of TRIZ. In particular, it forms many of the so-called "lines of development" of TC, which are one of the most striking, both effective and efficient tools of TRIZ. Of course, conclusions, methods and lines of development offered by this law and tools based on it are fully true for flows as well as for any other components of the system. However, there are also significant features, hitherto the law of increasing coherence and the law of streamlining are still not reflected in the literature (and practice) on both the law of increasing coherence and the law of streamlining.

One of the main parameters for any flow is its intensity.

Flow rate refers to the amount of substance, energy or information per unit time. For example, electric current ([A]=[Q/t]), power ([W]=[J/s]), petrol consumption (litre/hour), semi-fuel flow (kg/sec), car traffic (cars/hour), etc.

The intensity of the flow at the inlet to the channel, is equal to the power of the source (in the more general case, the part of it that works for the given channel). It should be noted that, unlike noxious flow, the source of useful flow is often amenable to change: often the only useful function of this component of the system is precisely to generate that useful flow.

The pattern is that

- as the system evolves, the conductivity of the useful flux channel becomes increasingly consistent with the source power.
- as the system evolves, the conductivity of the main utility flow channel becomes increasingly consistent with the flow conversion rate of the consumer.

Note:

The current version is happening

- Increasing the conductivity of useful flows

  Or
- Improving the efficiency of useful streams

In ordinary Russian, this sounds like the need to either increase the conductivity of the channel or change the flow in some other way. No advice is given as to when to apply which sub-trend. In this form, the law is certainly correct, but completely useless ("agree to meet either on Friday or some other day").

The need to harmonise three different objects at once – the flow source, the flow channel and the operating body – is a considerable challenge here. But this is why it makes sense to split a single trend into two separate ones.

5.3 Reconciliation of auxiliary utility flows by intensity

The general pattern is that, as the system develops

- the conductivity of the auxiliary useful flow channel is increasingly matched to the source power
- the conductivity of the auxiliary useful flow channel is increasingly matched to the flow conversion rate in the consumer.
- the intensity of the auxiliary utility flow is increasingly in line with the intensity of the main flow

The first two theses are exactly the same as for the main flow and seem to be unconditional. The third point relates to the fact that the auxiliary flow by definition has no independent value, but is used to increase the efficiency of the main flow (additives in gasoline, water dissolved salts in heat exchangers, catalysts, lubricating oil in moving parts of machines, service and meta-files in the information flow, etc.). The requirement to harmonise these flows with the main flow for which they are introduced into the system also seems understandable.

This complicates both analysis and problem-solving considerably – four or six objects need to be mutually agreed upon at the same time! But this is why an explicit requirement for such harmonisation is of great practical importance: there are countless situations where an obvious requirement has become a default requirement and, with the passage of time, simply forgotten.

A typical example of auxiliary flow in an internal combustion engine is the oil flow in the engine.

In this case it is absolutely essential to match the flow rate to the operating conditions of the engine. This is achieved by feeding the oil pump (flow source) from the motor axle. In this way the intensity is matched to the engine operating mode (feedback mode). In the absence of this matching, excessive flow would, at the very least, lead to an unnecessary loss of capacity. The disadvantage of this (feedback) solution, however, is the need for a larger oil pump, which is not used to its full capacity most of the time.

A very important frequent occurrence, significantly reducing the number of simultaneous of the subsystems to be reconciled is a complex flow: if the number of The amount of auxiliary resource is unambiguously linked to the amount of the main resource and They are used strictly at the same time and in the same place (additives in petrol, salts in water solution, metafiles in the information flow...), in an effective way The main reason for this is their pre-mixing (often still in a supersystem). In this case, no additional channel is required, nor is it agreed (corresponds to the flow's use of a channel for another flow from an active version of the law).

Thus, an important recommendation emerges:

- If the main and auxiliary streams are unambiguously linked to each other, the streams must be combined into one integrated stream,
- if there is no unambiguous match – enter it.

The situation can be seen as a manifestation of the law of coagulation based on the merging of alternative systems.

Of course, in this case, as in all others, choices must be made based on the specific task at hand. When the consumer sees the flow of Coca-Cola, for example, the factory technologist must look at the flow of individual components, which are managed and behave differently. Or when working with files: the user may see a single file of information in front of him. The programmer, on the other hand, must also see the entire set of metafiles that accompany the file. And so on.

Similarly, referring to the operation of "another law", in this case the law of increasing coherence, should not mean ignoring this operation in flow (as in any other) analysis.

Another typical example of auxiliary flow in an internal combustion engine is the additive flow to the petrol. Since these additives are needed strictly at the same time, in the same place and in a rigidly specified proportion to the petrol, matching is done by pre-mixing back in the supersystem. But since there is always a price to pay for everything, when the use of this method will result in a loss of controllability of the system (whatever petrol you use, that's what you drive, even if the driving conditions have changed).

5.4 Flow buffering as a matching tool

The presence of buffers (buffers) between the flow source and the product is

- An important indication of insufficient source and channel or channel and product coherence
- The performance data can be analysed, allowing the shortcomings to be seen immediately, in the earliest steps of the analysis.

But at the same time

- The simplest and therefore very common way to deal with existing misalignment.

The causes and consequences of buffering are varied and could be the subject of a separate study. However, it would be redundant in this paper.

Integrated resource sources

An embedded source is created to provide system autonomy from an external source. Therefore, functionally, the integrated source is a typical buffer between the over-system flow source and the channel. The inconsistency lies in the practical absence of a primary flow channel during the operating phase of the implement. But at the same time, the embedded source is the source of flow in relation to all downstream system elements. One of these two features of the embedded source must be chosen depending on the purpose of the analysis.

The need to consider embedded sources in the flow analysis refers us to the law of increasing completeness of system parts, but the same need also shows the limitations of this law: an embedded source is after all only a buffer at least in the sense that it accumulates a resource coming from somewhere outside. But any transportation and storage of a resource (especially if it involves its conversion) inevitably requires direct material costs, costs of system operability resource, complication of the system, etc. Therefore, an embedded source is used only and exactly as a necessity, which completely contradicts the basic thesis of the law of increasing completeness of parts of the system.

Transport systems are very characteristic in this sense. Railways, when they reach a certain volume of traffic, turn out to be the cheapest of such systems. At the first opportunity, they are converted to electric propulsion, even at the cost of reduced autonomy – i.e. the embedded source is removed.

The typical (but not the only) integrated source of fuel in a vehicle engine is the petrol tank and an additional canister. The above-mentioned inconsistency in terms of volume requirements is fully evident here: In rally or touring cars, the gas tank is made as large as possible, and the canister is also put in the boot. For ordinary road trips on the more or less developed road network, the canister is left at home. For racing on the track, the size of the tank is made as small as possible (F1 cars are refueled every time they change tyres, saving on the weight of the car).

5.5 Manageability of useful flows

The control system is a very important element of the flow system in any vehicle. It has been completely ignored in the current version – apparently because it is detailed in the law of increasing manageability. But, as in the case of increasing coherence, the result was that flow control was completely lost in the flow analysis! Meanwhile, any useful flow is bound to have a control system, at least at the on/off level.

Harmful flow also has an AC, otherwise it would simply not work (due to the law of completeness of parts – see, for example, "Harmful System" by V. Lenyashin [18]). However, in most cases, the EA of the harmful flow is either not explicitly expressed (and is formed by other components of the system), or the EA of the useful flow acts in this capacity.

The following recommendation arises here: give the harmful flow an explicit control system in cases where its amplification could lead to system malfunction or unacceptable harmful effects in the supersystem.

An example in the ICE:

- The petrol pump is controlled by switching on the main engine
- When the motor overheats, it shuts down (otherwise it will still shut down, but in crash form).

The development of a flow management system is one of the few sub-trends of the RES, for which the typical clauses "as a rule" and "statistically reliable" are not only unnecessary, but also unacceptable. The necessity of the useful flow management subsystem follows from the fact that at different stages of the TS life cycle its consumption of flow is different (at least at the level of yes/no).

So: in any system with an explicitly dedicated usable flow, there is ALWAYS a flow control subsystem. The development of this subsystem is entirely determined by the law of increasing controllability.

Two types of flow rate control

By separating to analyse the flow source and its channel, two types of control also appear: conduction control of the channel ("valve") and flow intensity control ("pump").

The "valve" type of control generally looks easier to implement and is therefore used much more frequently. However, a "valve" has a significant disadvantage over a pump: it necessarily slows down the flow – it is an artificially created bottle neck!

Therefore, it is often more progressive (but usually more difficult to implement) to use the "pump" control, when we do not touch the channel, but directly regulate the intensity of the flow itself. The sub-trend of replacing "valve" by "pump" is not frequent, but always useful when possible.

It is clear that the valve in the useful flow channel is a sub-system of flow intensity matching. In this case, the channel itself is redundant on average, although at any given moment its conductivity is matched to the flow consumer. In accordance with the above, the maximum conductivity of the useful flow channel must be equal to the maximum for all possible modes.

This means that the duct is not being used to its full capacity on average. Therefore, the mere presence of a "valve" in the flow channel means that there is a technical contradiction of the following kind

- The conductivity of the channel must be equal to the capacity of the flow consumer in order to ensure optimum operating conditions and the lowest system cost

BUT

- The conductivity of the channel must be higher than that of the flow consumer in order to ensure the manageability of the subsystem

Similarly, the "pump" control requires that the channel conductivity be higher than average and the flow does not fully utilise the channel capacity – a similar, though different, contradiction arises in form. In the case of a "pump", the source capacity is also excessive.

Thus, the mere presence of flow places contradictory demands on the flow management system.

The nature of the contradiction clearly suggests the direction and method of development of the subsystem – trimming aimed at reducing the said redundancy[2].

6 Features of closed flows

Above, a closed flow is defined as a flow that returns to the source, i.e. a flow whose channel is closed.

Of course, when passing through a channel and a consumer, the flow always changes some of its parameters, so, in principle, any closed flow can be considered as two different flows consisting of the same material components, provided that the consumer of the first is the source of the second and vice versa. Besides, no flow is absolutely closed. Sooner or later, any flow will become open. At least – as a result of physical wear and tear of the channel. However, in a rather large number of cases, the flow can be considered completely closed during the whole life cycle of a vehicle. The use of this concept often facilitates the analysis.

An important feature of closed flows is also that they are always matter flows.

ICE examples of closed-loop flows are:

- Coolant flow is a useful flow.
- The oil flow in the engine is a useful flow,
- The flow of contaminants in the oil is a harmful flow.

Other examples are the circulating water in a huge number of different technical devices, the flow of municipal transport moving from ring to ring and back; the flow of working fluid in a Stirling engine, the flow of ions in batteries, etc.

In general, closed flows have all the properties of a flow, but their features provide additional opportunities for optimisation.

6.1 Closed flow channel

A closed flow channel can generally be of three types:

- Separate for forward and return flows that move in two different duct branches (e.g. coolant or circulating water flow),

[2]It is not unreasonable to recall, however, that such a disadvantage, and therefore such a direction, is always available.

- Reversible, where forward and reverse currents move through the same channel (working body in a Stirling, ions in an accumulator),
- Circular, when there is no explicit source and consumer (trains on a circular underground line, circular currents).

The direct branch of a closed flow is the part of the channel through which the flow moves to its consumer. The return branch is the part of the channel through which the flow returns to the source. For the divided channel it is spatial separation. For a reversible channel, it is a temporal division (part of the time the same physical channel acts as a direct channel, part of it acts as a return channel). For a circular channel such a division does not make much sense. For the sake of generality, we can consider the whole channel to consist only of a forward branch.

6.2 Useful closed loop flow

On the direct branch of the closed utility flow channel, all the flow improvement rules, both those summarised in this paper and those adopted by each specific branch of engineering, are fully applicable.

But on the return branch of the channel, a closed useful flow is ALWAYS harmful (not performing a useful function in the system, it necessarily consumes some resources: at least it is the return channel itself, which must be laid, and energy to be spent on movement). Therefore, all rules formulated for harmful flows, in particular those formulated by Litvin and Lyubomirsky, are fully applicable for the return channel of useful closed flow: it is necessary to ensure as high conductivity of the channel as possible, as high flow intensity as possible, to try to give some additional functions to the flow.

6.3 Harmful closed-circuit flow

For this type of closed-loop flow, all the rules formulated for harmful flow in general are also true, but there is an important feature: in this case, the subject of the harmful function repeatedly passes through the product, so that its harmful impact is also multiplied.

In this case, in contrast to the beneficial closed-loop flow, which, as it were, changes "polarity" on the return branch becoming harmful, the originally harmful closed loop remains harmful everywhere.

Therefore, the presence of harmful closed flow in a system is always a sign of a more serious defect than harmful open flow.

But there is also an additional method of eliminating this disadvantage: you need to disconnect this flow – essentially the same sewage intake.

For example, in the case of a closed flow of contaminants in the oil (which includes abrasive particles, which cause faster engine wear), a conventional filter is used, which inhibits the flow. But it makes sense to aim to open the flow, i.e. to remove contaminants.

7 Features of the carrier flow

7.1 Media substitutability

The main (often the only) useful function of the carrier flow is to move the carrier flow. Therefore, the carrier flow is most often not the only possible option and can be substituted.

For example:

- The explicit trend towards replacing petrol engines in the car with gas engines, alcohol engines and abandoning the internal combustion engine in favour of electric motors is an attempt to replace the energy carrier flow.
- A well-known example: the successive replacement of energy carriers in different ovens: from firewood (energy carrier presented in chemical form) to the magnetic field (induction heating).
- Various heating and cooling tanks can be used: water, alcohol, ethylene glycol, etc.
- The emergence of mobile phones is entirely determined by the shift to a different medium.

The sub-trend is not universal, but the caveat "as a rule" could even be removed for the sake of the methodology: even if it fails, an attempt to see alternative carriers could prove useful. In any case, it is not easy to find a non-alternative medium (it is easy to find one where the alternative is economically inefficient or technically unrealistic at the current level of technology – but it is very difficult to find a completely non-alternative medium).

7.2 Harmfulness of the carrier

The carrier flow by itself (if we abstract from its function of carrying the actual useful flow) is almost always harmful (everything it does in the system besides its main function is unnecessary, and resources are always consumed). Therefore, its optimisation is usually an important area of TC development.

In addition to the general rules for improving flows, there are also specific areas (sub-trends).

7.3 Basic carrier flow optimisation techniques

From these two main properties of the medium (especially the latter), the main techniques (sub-trends) of its optimisation also emerge:

- Increase the flux-functional density on the carrier (up to and including changing the carrier).

  For example:

  - Replacing air cooling systems with water and then various alcohol-containing liquids.

  - The use of higher operating voltages in electrical power systems. This is by no means always possible for other reasons (in particular for safety reasons), but in power transmission lines, for example, it is a long-standing and very effective trend.
  - Denser transport load (transport is a typical carrier of useful "cargo" flow)
  - The latest revolution in computer science is the advent of broadband data transmission systems
  - An increase in productivity can well be thought of as an increase in the density of useful operations per unit of effort expended – an example that may not be entirely correct, but is absolutely relevant.

- Reducing the cost of the medium.

  Of course, this is relevant for all types of resources. However, while this may not be justified for the main carrier flow (there is a high risk of quality loss), it is always relevant for the carrier flow, which will no longer be present in the final product.

  - The trend of replacing gasoline with "alternative fuels" accelerates significantly during periods of expensive oil (although it does not abate during periods of cheap oil)
  - This can be seen very clearly in the desire to reduce the cost of industrial packaging in every possible way

- Giving the carrier stream additional useful functions.

  For example:

  - Giving the consumer packaging functions of information, protection, etc.,
  - Use as cassettes for group machining of future instrument casings.

7.4 Use of sub-trends for ancillary beneficial and secondary harmful flows

Carrier flux is a special case of an auxiliary useful flux BEFORE release from the functional and a typical secondary harmful flux AFTER. Therefore, all the rules of optimisation set out in the relevant paragraphs are correct, but with mandatory consideration of BEFORE/after (carrier channeling would be inappropriate before release from the functional; likewise, after use, no matching per se is needed any more – we need to get rid of it).

7.5 Closed (circulating) carrier flows

The stream-carrier can very often be used repeatedly, returning to the point of 'loading with functionality'. But this is not always done: for a significant part of the journey/time the returned 'container' spins empty. The criterion here is, in general, clear: if the cost of the return is lower than the cost of the carrier stream itself, then it should be returned. And vice versa.

Accordingly, two sub-trends emerge:

- Reducing the cost of the medium (see above)

- Reducing the cost of carrier turnover (see 'closed-loop flow').

These two sub-trends may well be developing simultaneously.

- A typical example: recyclable containers. The blue dream of production workers is bulk-free production. But as this is not often possible, huge efforts are spent on realising these two sub-trends. A typical example: collecting empty bottles.
- At the same time, in-plant intermediate packagings are very common – turnover is short, easy to manage, etc.
- Another example: freight transport. This is why they try to use piggyback transport at every opportunity (quite large companies on the outskirts of big cities are making good use of this trend). Universal containers and the transport systems themselves, which are strictly tailored to such containers, also do a good job of increasing turnover.
- If water is used as the heat transfer medium, it is often discharged into the sewer system after use. But as soon as some kind of brine, tosol etc. is used – it almost always becomes multi-turnable.

A general rule of thumb (optional, but often implemented) is that if the carrier flow is completely circulating in the system, it can be made multiturn and is usually very efficient. If, however, the flow goes out into the supersystem, its return efficiency drops dramatically.

A striking example: water recycling systems within a single production facility, even a large one, can easily be closed, but for a small village (often much smaller than the production facility in question) almost never.

8 Streaming analysis algorithm

There are two main approaches to compiling methodologies for analysis and working in TRIZ. They can be called "step-by-step strategy" and "step-by-step algorithm".

A step-by-step strategy describes the main directions, leaving enough room for imagination and creativity for the solver. A step-by-step algorithm implies a literal or almost literal adherence to the prescriptions that are prescribed in sufficient detail. Typical examples are ARIZ-68 [19] consisting of 5 parts divided into a total of 25 steps and ARIZ-91 [14] consisting also of 5 parts but divided into more than 80 steps and supplied with a few dozens of comments. Quite often such a step-by-step algorithm is also provided with an algorithm diagram by type:

Include Diagram

Taken from the cited work of O. M. Gerasimov [9].

"Step-by-step strategy" is often thought of as "easy TRIZ" and "step-by-step algorithm" as "advanced TRIZ". This is not entirely true. For example, G. Ivanov's ARIP [20] is a typical algorithm, although it is aimed at easy perception by an untrained (in terms of TRIZ) listener.

It seems that the step-by-step strategy is more oriented towards mastery and use by a specialist who remains an expert in his or her local field, simply applying TRIZ as one of his or her working tools along with others.

The step-by-step algorithm requires considerably more, if not knowledge, then skill TRIZ application and is used when a problem proves to be unsolved by traditional methods. In practice, it is difficult to imagine a production engineer being able to go through all the steps of ARIZ-91 in detail and thoughtfully. TRIZ professionals also use this complicated tool only when necessary. But on the other hand, when the problem is not solved head-on, there is often nothing else to do.

Thus, both approaches look valid each in its own context. Therefore it seems important to have two versions of the methodology for each TRIZ tool.

There is also a third approach for flow analysis. It has been repeatedly mentioned above that flow analysis is a special special case of functional analysis. Therefore, a special tool for organising such a transition is desirable.

Therefore, this chapter provides three algorithms for different applications of analysis.

8.1 "Step-by-step algorithm" for conducting a flow analysis

1. Select the system to be analysed, select the target gap. Draw up a component model for the flows and associated static components

   Note 1. As with FM, it is important to select components of the same system level, i.e. that are not components of each other. It is advisable to limit the number of components and threads to no more than 6-9.

   Note 2. It must be remembered that each material stream is always accompanied by auxiliary streams: the energy stream and the information stream. Excluding these auxiliary flows from consideration is possible, but it should always be a conscious choice. Particularly because the management of ancillary flows is often an important tool in the management of the main flow. Excluding them as early as the component model stage closes this possibility.

2. Make a model for the main flows (useful and harmful – i.e. those defined by the principle of action).

   Note 3: The model is constructed as a graph in which the nodes are static model components and the links are flows, as shown in Appendix 2 of the Algorithm. The model takes into account:

   - Availability of an additional time axis
   - The need to separately identify useful and harmful flows and the area/time when a flow changes from a useful to a harmful one
   - Availability of flow transformations
   - the places where parasitic flows originate and exit into the supersystem
   - the presence of closed streams

3. If necessary, add energy and information flows to the model

Note 4: The order in which the flows are introduced can be changed, e.g. if the project is "energy" or "information" in nature. But when different types of flows are considered in the model, this order is appropriate.

4. If necessary, add parasitic flows to the model.

   Note 5. Different types of flows are colour coded in the model column. In the table, the designation is in a separate column, although it is more convenient to duplicate the colour for clarity.

5. Determine the values of the main parameter of each of the streams and assess the level of that parameter on an Excessive/Adequate/Inadequate scale.

   Note 6: Most often (but not necessarily!) the main parameter for flow is its intensity ([A=K/s], [m3/s], etc.).

   It is often difficult to set absolute values for parameters. In this case you should at least specify a possible range.

6. Mark harmful and parasitic flows and inadequate flows on the graph with different colours

7. Due to the formality of the procedure in steps 2-4, there may be flows in the model that are not realistically flowing. Remove them from the model.

   Note 7. An important, but optional, feature of such a flow is the absence of parameter values as such.

8. Make a model in tabular form

   Note 8: A table and a graph can be made at the same time. But more often it is more convenient to make the graph first and then the table. The graph shows the structure of the flows, while the table shows their parameters

9. Given the chosen target weakness, remove insignificant (non-significant) flows. In the same step, remove those flow channels where the flow does not undergo any meaningful change

   Note 9. Flows of low absolute intensity as well as flows that are not significant within the scope of this project can be taken as insignificant.

   Note 10. During the analysis we do not yet know in advance which flow is important (otherwise no analysis is needed). Therefore it should be done very carefully. When in doubt, it is better to leave an unimportant flow in the model than to remove one which may later turn out to be the key flow. In case of serious doubts, step 8 can be skipped.

10. Remove channels from the model graph (without removing them from the table)

    Note 11. Flows undergo minor changes in the channel. Therefore they can be removed from the graph to simplify the visual perception. However, the channels must remain in the tabular form of the model!

    At the same time the correct channel definition is checked: if a component makes strong changes to a stream, it is more correct to classify it as the receiver of the stream (and at the same time the source of the next, transformed stream).

Note 12. Points 8-10 are performed to simplify the model. In the case of a sufficiently simple and illustrative model, the following may be omitted

11. Refine the table form of the model according to the results of items 9, 10, 11.

    Note 12a. Points 9-12 are intended to simplify the model in case it proves to be overloaded with unnecessary components. For relatively simple models, the points can be omitted. In the FA, these points correspond to the recommendation of iterative procedures.

12. Identify sections of the flow model that have disadvantages. The disadvantages are:

    - flow areas with inadequate parameters (including bottle necks and stagnant areas)
    - areas where the channel changes (disrupts) the flow or the flow changes (disrupts) the channel
    - grey areas
    - high-loss flow conversion points
    - points of occurrence of parasitic flows

    The selection should be made by introducing additional columns in the tabular form of the model.

    Note 13. Flaws can also be highlighted on the graph. However, very often the graph becomes overloaded with different designations and difficult to perceive visually. Therefore, the analytical points of the algorithm need to be tabulated, putting only the information that is perceptible (based on the project objectives) into the graph.

    The analytical part of the algorithm

13. Identify fragments with (and interacting with) homogeneous flows. Formulate (clarify) disadvantages.

14. Classify all harmful or inadequately performed beneficial flows by classification attributes (see Appendix 1 "Flow Classifier").

15. Write down a list of the shortcomings identified and rank them

    Note 14. When ranking, use the data from step 12. In addition, it may be necessary to construct a causal chain of deficiencies.

16. Formulate the flaw elimination objectives with respect to flow parameters or channel elements, taking into account the recommendations set out in Chapters 4-7 and Appendix 1 "typical methods for flaw elimination in a flow model".

17. The basic principles for remedying the shortcomings found.

    - Deficiencies that do not form a contradiction are usually remedied by sectoral techniques and methods.
    - Gaps that form conflicting requirements for flows and/or related components should be resolved first – using the techniques and recommendations described in the chapter "flow classification"

- For deficiencies formulated in relation to channel parameters – See chapter "Transition from flow analysis to functional analysis"

  Note 15. Basic (typical) channel properties that are relatively easy to change:

  - Channel conductivity parameters
    * Bottle neck
    * Stagnant (buffer) zone
    * Channel length
    * Specific channel resistance
    * Density of flow in the channel
    * Number of flow conversions
  - Parameters for flow variation
    * Grey area
    * The channel changes (disrupts) the flow
    * The flow changes (destroys) the channel.
  - For deficiencies formulated in relation to flow parameters – formulate problems for source/consumer pair. See appendix 1.

Note 16. For example, if you want to increase the voltage in a transmission line – start with the transformers and only post look at the line itself. If we want to increase the pressure in a gas pipeline – look at the booster compressor and only then think about the pipe

Note 17. See appendix 2 for an example of this algorithm. The streaming analysis shown in this appendix was performed during the execution of a real project for Samsung SDI. Due to confidentiality conditions, a number of numerical values have been omitted. In addition, some steps are not shown in full but as examples (Sanky diagrams, solution examples). This example is an example of a complex analysis, after unsuccessful attempts to perform a flow analysis using the traditional method.

8.2 Transition from flow analysis to functional analysis

As already stated, flow analysis is a special case of functional analysis. It is often necessary to consider the interaction of static components not only with flows but also with each other. The procedure for changing from flow analysis to functional analysis is described below.

1. Building PMs using the proposed methodology

2. Identification of flow deficiencies as recommended

3. Clarification of the deficiencies identified, identifying the type of deficiencies:

   - Inadequate flow parameters and functions
   - Inadequate and harmful flow functions,
   - Excessive payback factor for the functioning of the stream
   - Inadequate channel parameters and functions
   - Inadequate and harmful channel functions

- Excessive payback factor for the formation and functioning of the canal

4. Build a functional model for the components associated with the problem stream and conduct a standard FA.

   Note 18. In fact, this is a standard and widely used technique by practitioners: construct a detailed deeper system level FM for the problematic part of the system identified by the higher level models.

5. Formulate the disadvantages associated with the interaction of static components, formulate tasks to eliminate them.

8.3 A "step-by-step strategy" for conducting a flow analysis

In comparatively simple cases this may be sufficient. Recommended for specialists in specific fields.

1. Identify streams.

   Write out the existing flows in the system that are relevant to the project objective

2. Specify the type of flow: useful/harmful/parasitic.

   For useful flows, specify the level of fulfilment of the main function: adequate/insufficient/abundant

3. For each stream, define source, channel, receiver.

4. Classify the flows.

   To classify according to chapter 3 "Flow types"

5. Articulate the disadvantages.

   Accept harmful and parasitic flows as disadvantages, as well as inadequate performance of the main function by the useful flow

6. Formulate objectives to address the shortcomings.

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