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# OPTIMIZATION PROBLEMS IN DESIGNING AUTOMOBILES

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**Abstract.** A mathematical model of optimization problems in designing automobiles is suggested and requirements raised are defined taking into account the main technical and economic characteristics of the automobile. The optimality criterion of the integral parts of the automobile is presented. The system approach to the theory of parametric optimization based on generalized models is used and the algorithm for solving the considered problem is offered.

**Keywords:** mathematical model, optimization, automobile, design, system approach.

## 1. Introduction

Under transition to market economy, the development of scientific concepts defining parametric optimization in automobile design is particularly important. Based on the theory of parametric optimization, the strategy of automobile industry development embracing the measures of environment protection, the needs of customers, the use of alternative power sources (e. g. electricity, hydrogen, biomass and sustainable energy sources) as well as control over exhausted burnt gases (zero toxicity automobile), a decrease in noise level and the use of intelligent transport systems (e. g. interactive data exchange, intelligent automobile) can be created (Дьяков 2003).

A great number of solutions to engineering are based on the mathematical theory of optimal experiment. The method of *morphological Zwicky box* (Ермаков и Жиглявский 1987; Parnell *et al.* 2008) used for solving optimization problems is considered to be ineffective when the raised requirements for the automobile are growing. The system approach to solving the above introduced problem based on generalized models yields much better results.

The system approach takes into account the essential operating characteristics of the automobile. A user of a particular transport facility may be represented by a number of people (e. g. repair and maintenance staff, engineers, technicians etc.) rather than by a single person (a driver), and therefore their needs should be taken into account by submitting a mathematical model.

## 2. Review of the Papers Discussing the Issues of Transport Optimization

Researchers in many countries are trying to solve the optimization problems of transport as well as of other related areas. Let's have a look at several scientific studies carried out on the subject of optimization in transport.

Bagdonienė (2008) investigated the optimization of loading facilities at the terminal. The problems of stock management and a proper choice of transport facilities were defined and analysed taking into account the relationship between the costs of transportation, vehicle capacity and the size of cargo lots. The optimal vehicle capacity for a particular lot on the routes for taking cargo away and the periodicity of cargo delivery were determined using mathematical statistical methods.

Brauers *et al.* (2008) examined multi-objective decision-making for road design. Multi-objective analysis is a popular tool to solve many economic, managerial and construction problems. The objective of research is to develop and implement a methodology for the multi-objective optimization of multi-alternative decisions in road construction. On the basis of the Ratio Analysis (MOORA) method, multi-Objective Optimization for investigation was selected. The method focuses on the matrix of alternative responses to the objectives. A case study demonstrates the concept of the multi-objective optimization of road design alternatives and the choice of best road design alternatives.

Tanczos and Torok (2007) studied the linear optimization model of operation aimed at increasing trans-

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portation efficiency in urban areas. The efficiency of urban transportation is getting more important because of the increasing rate of mobility demand. To plan, control and organize urban transportation in the most efficient way, we also need to consider the main aspects of land use. To consider both of the above-mentioned urban planning areas simultaneously, models capable of analysing all their restrictive factors in the simplest way should be developed. This problem may be solved by simulating the urban area through a linear programming model.

Tong *et al.* (2007) examined time-cost-security tradeoff optimization in project logistics based on decision network planning. Project logistics is the project of transporting large industrial equipment such as oil production platforms, chemical processing equipment, power generating equipment etc. Apart from the rigorous requirements of time, cost and security, comprehensive optimization of transportation plan is one of the major tasks at the preliminary stage. Since several choices of the available operations can be made, the selection of transportation plan is a multi-objective *NP*-problem. In this paper, a tradeoff optimization model of time-cost-security based on the model of decision network planning was developed applying multi-attribute utility function theory. The self-adaptive genetic algorithms applied to solving the model yielded satisfactory decision results. A case study of plans for transporting and installing chemical processing equipment was provided to verify the validity of the model and the feasibility of the solution method.

T. Marasovic and R. Marasovic (2007) studied road maintenance and optimal route planning. Optimal route planning is a subject of interest in control systems (e. g. planning robot motion) associated with people, vehicles or information guidance (traffic management). Basic transport optimization methods developed on the scientific principles of Operations Research, however, cannot solve all 'travelling and routing' problems. In the considered paper, the novel idea and the newly developed method supplied by a suitable program for optimal route servicing are suggested. Optimal time saving route is planned according to the idea that under different priorities, all roads included in a particular map sometimes have to be passed (serviced) by one or more service vehicles.

Migliore and Catalano (2007) investigated urban public transport optimization considering bus routes and using neural network-based methodology. The paper describes an approach to planning bus lanes in the urban road network in the urban area of Palermo. The proposed modelling tool adopts a multi-agent objective function expressing trade-off between the interests of diverse stakeholders related to the generalized transport cost for car drivers and travel time for public transport users. The reaction of car traffic to a certain planning scenario was simulated by the *DUE*-assignment technique while a positive impact of the modal shift on the objective function was tackled by attaching a suitable weight to time saving for bus passengers. The rise in the bus travel speed owing to the bus lane solution was predicted for a set of urban roads by a neural network, so as to take into account many quantitative and qualitative road attributes. The optimal location pattern of bus routes was searched by a greedy heuristic that through a step-by-step strategy was building the problem solution by keeping the best alternative at each stage.

Azemsha (2006) investigated the optimization methods of rotational latency of the inverse loading of trucks on international routes. The increase in the efficiency of the international car transportation of cargoes is a significant problem. Recently, to work out a solution to the problems of delivery, information systems based on the *Internet* technology and containing information on cargo transportation and available automobile transport facilities have been created. This allows us to solve the problem of loading transport facility in inverse direction. However, the problem of making an optimum decision concerning return loading arises. This paper focuses on the technique determining the waiting time of the return loading of the vehicle running in any direction which could ensure the maximum economic effect of the performed work.

Davulis (2006) investigated the model for the sustainable development of transport infrastructure. Constantly increasing volumes of passenger and cargo transportation require continuous transport network development as well as the renewal and updating of its elements. On the one hand, transport is a branch of economy that requires a lot of resources for its effective operation. On the other hand, the development of transport infrastructure may cause negative effects on the environment. The optimization model allowing the choices of the most efficient ways of developing transport infrastructure was offered. The criterion of the model involves the expenses needed for compensating negative effects caused by the development of transport infrastructure while the system restrictions on the model involve the restrictions of the negative effects of infrastructure development. The model allows the optimization of the costs of developing transport infrastructure without exceeding the limits set for negative effects produced by it.

The surveyed research papers disclose the range of optimization problems in transport and other related areas.

The authors of the paper offer a mathematical model of optimization problems and define requirements raised to designing automobiles, considering the essential technical and economic characteristics of the automobile.

### 3. Choosing the Optimality Criterion

Suppose that a transport enterprise has $k$ various objectives (aims) e. g. to make the automobile more economical, to raise its average speed and reliability etc. Each of the aims or needs may be described by the number $\alpha_i$, showing how important and urgent it is (Дьяков 2003). It is clear that the needs are changing in time depending on the state of the automobile as well as on a particular transport enterprise and its environment.

At any particular moment of time, the needs (aims) of a transport enterprise can be described by a set (vector) of attributes:

$$M = A(\alpha_1, \alpha_2, ..., \alpha_i, ..., \alpha_k);$$
$$\alpha_i \geq 0;\ i = 1, 2, ..., k,$$

where: the urgency of the need can not assume negative values, and therefore in the absence of $i$-th need, $\alpha_i = 0$.

Suppose that a transport enterprise has a system for achieving its aim. Then, the action of a designer will be aimed at achieving the control function i. e. the equality $z = z^{\bullet}$ by means of control ($u$). Let us assume $z$ to be the state of the automobile (object) described in terms of objectives (aims) $\{z^{\bullet}\}$.

The translation from one language to another is performed by the function $f$ i. e. $z = f(y)$, where $f(y)$ is the specified objective function.

A designer should have a special objective function $\mu(\bullet)$, i. e. a specific function of the non-optimality of construction determined based on a set of all possible objectives (aims) $\{z^{\bullet}\}$.

This function allows us to compare the aims $z_1^{\bullet}$ and $z_2^{\bullet}$ as follows:

- if $\mu\left(z_1^{\bullet}\right) \leq \mu\left(z_2^{\bullet}\right)$, then, the aim $z_1^{\bullet}$ is preferable to the aim $z_2^{\bullet}$;
- if $\mu\left(z_1^{\bullet}\right) = \mu\left(z_2^{\bullet}\right)$, the aims are equivalent.

The choice of the optimal aim may be reduced to the solution of the problem $\mu\left(z^{\bullet}\right) \to \min\limits_{z^{\bullet} \in \left\{z^{\bullet}\right\}} \Rightarrow z^{\bullet\bullet}$, where $\mu(\bullet)$ may be defined as the weighted sum:

$$\mu(\bullet) = \sum_{i=1}^{k} b_i \alpha_i,$$

where: $b_i > 0$ is a constant coefficient ($i = 1, 2, ..., k$); $\alpha_i$ is 'weight' describing the urgency of $i$-th need (objective) for a transport enterprise.

These values can be determined by expert evaluation. The realization of the selected aim should change the needs towards the improvement of the applied (functional or structural) model:

$$M_1^{\dot{z}} - M_2,$$

where: $M_1^{\dot{z}}$ is the initial state of the original model; $M_2$ is the model obtained as a result of the realization of the aim $z^{\bullet}$.

It is clear that model $M_2$ should represent a minimized objective function. For this purpose, the relationship $M_2 = f(M_1, z^{\bullet}, s)$ should be established, where $s$ is the state of the environment at the moment of choosing the aim $z^{\bullet}$.

In the simplest case, $s = (x, y)$ i. e. it is the state of the environment (loading modes, servicing intervals, method of storage, road surfacing etc.).

Given the above relationship, we could substitute it to $\mu(\bullet)$ and obtain the required function $\mu(z^{\bullet})$, which, when minimized, would clearly define the optimal aim of the customer.

The described mechanism presenting optimal aims may serve as a basis for developing a formal optimality criterion. However, for this purpose, two models $\mu(M_1)$ and a generalized model $\mu\left(M_{2\dot{z}}\right)$ ensuring the changes in the objectives (needs) $f(\bullet, \bullet, \bullet)$ based on the aims of the customer $z^{\bullet}$ should be available. A model may be considered to be adequate if it accurately reflects the parameters of the investigated automobile. The accuracy is determined by the extent of matching the output model parameters to their true values. The error of the model $\varepsilon_M$ with respect to $m$ of all considered output parameters is expressed as:

$$\vec{\varepsilon}_M = \left(\varepsilon_1, \varepsilon_2, ..., \varepsilon_M\right);$$

$$\left|\vec{\varepsilon}_M\right| = \max_{\in|1:m|}\left|\varepsilon_j\right| \quad \text{or} \quad \left|\vec{\varepsilon}_m\right| = \sqrt{\sum_{j=1}^{m} \varepsilon_j^2},$$

where: $\varepsilon_j$ is a relative model error with respect to $j$-th output parameter:

$$\varepsilon_j = \frac{\bar{y}_j - y_j}{y_j},$$

where: $\bar{y}_j$ is output parameter calculated by using the constructed model; $y_j$ is the value of the same parameter obtained in testing the automobile under the controlled conditions.

If the admissible modelling error is $\varepsilon_{\lim}$ and the area, where $\varepsilon_m > \varepsilon_{\lim}$, may be defined, then, this area is considered to be adequate to the model.

The universal character of the model is described by the number and scope of representing internal, external and output parameters. The more parameters are represented by the model, the more versatile it is. However, in this case, the costs of calculation tools used for its implementation are considerably growing.

## 4. Optimality Criteria Considering the Level of System Sophistication

Multilevel and one-criterion optimization systems are used for automobiles. The multilevel system includes:

- level 1 – a mathematical model generally considers the essential automobile characteristics;
- level 2 – separate units are considered;
- level 3 – automobile parts are analysed.

Each level includes the objective function as well as the constraints with the variable, the right-hand side of which is limited by the admissible values and constant parameters.

Specific quantities of overall costs in the area of manufacture and maintenance referred to the annual output are used as the objective function at the upper level.

The main principle of searching for the lowest material, labour or total expenses per automobile is stated in terms of mathematical programming as follows:

$$Z\left(x_i\right) \to \min, \quad R\left(x\right) \leq 0; \quad i = \overline{1, m},$$

where: $x = X_n = \Phi^n; \Phi^n \underline{\to n}$ is dimensional Euclidean space; $R_i\left(x\right) \in g\left(x\right), i = \overline{1, m}$ are the functions determined on the set ($x$) and assuming the real values; $R(x)$ denotes the limits imposed on the objective function

(e. g. smooth running, failure-free performance, braking characteristics, transmission gear parameters etc.).

The initial global task for the automobile may be generally described by the criterion for the upper level of optimization in terms of cost per unit:

$$Z(x)_1 = \frac{1}{W_a N_a}\left(\frac{\tau_{assemb}C_{whp}}{T_{rep}} + \frac{\tau_{maint}\dfrac{J(S)_{aot}}{J(S)_{maint}} + C_{rr}J(S)_i + C_{mr}}{T_{maint}}\right) \to \min,$$

and labour expenditure per unit:

$$Z(\tau) = \frac{1}{W_a N_a}\left(\frac{\tau_{assemb}K_{assemb}}{T_{rep}} + \frac{\left(\tau_{maint}\dfrac{J(S)_{aot}}{J(S)_{maint}} + \tau_{rr}J(S)_i + \tau_{mr}\right)K_{maint}}{T_{maint}}\right) \to \min,$$

where: $W_a$ is annual automobile output (capacity), thons·km/hour; $N_a$ is the number of the automobiles of similar design; $\tau_{assemb}$ is labour expenditure on assembling a particular automobile; $\tau_{maint}$ is labour expenditure on maintaining a particular automobile; $\tau_{rr}$ is labour expenditure on the routine repairs of a particular automobile; $\tau_{mr}$ is labour expenditure on the major repairs of a particular automobile; $C_{whp}$ is a worker paid per hour (hourly pay); $C_{rr}$ is the costs of the routine repair of the automobile; $C_{mr}$ is the costs of the major repairs of the automobile; $K_{assemb}$ is the proportionality coefficient of converting standard hours to kW·h in assembling a particular automobile; $K_{maint}$ is the proportionality coefficient of converting standard hours to kW·h in maintaining a particular automobile; $T_{rep}$ denotes the periods of repaying the automobile; $T_{maint}$ denotes the periods of maintaining the automobile; $J(S)_{aot}$ is the annual operating time in kW·h; $J(S)_{maint}$ means the intervals between maintenances in kW·h; $J(S)_i$ is the current operating time of the automobile in kW·h.

The essential difference between the criteria suggested and those commonly used is associated with obtaining the generalized quantitative evaluation of automobile construction.

The criterion of optimality of level 2 is chosen depending on a function of automobile units. For example, in determining the gear ratio, the ratio of fuel consumption $G_T$ per hour during the acceleration in the $i$-th period of time with full fuel feed to the overall mass of automobile $m_a$ is used as an objective function:

$$f(u) = \int_0^t \frac{G_T}{m_a}dt \to \min,$$

under the following conditions:

- thrust in $i$-th gear should ensure the specified value of the grip of the drive wheels;
- maximum speed should be higher than or equal to the admissible speed;
- motion stability in the lowest gearing should be within the limits set;
- acceleration characteristic should be within the specified limits;
- the mean acceleration in the specified gearing should exceed the admissible acceleration;
- the largest gradient overcome by the automobile with the full mass in $i$-th gear should exceed the maximum one;
- the condition of the cross-country capability of the automobile on earth road should be checked.

All conditions are described in terms of equations with variable parameters. The admissible values of conditions parameters are based on the standards (for example, *ГОСТ – Russian Interstate Standards, ГОСТ Р – State Standards of the Russian Federation, ОСТ – Russian Branch Standards, LST – Lithuanian Standards* etc.) are given.

**5. Results Obtained Approaching the Problem of Optimization**

First, the initial conditions and constant parameters were considered to deal with the problem of optimization. Next, on the basis of the acquired data, automobile motion while changing gears on different types of roads was simulated using computer.

The automobile considered has the following design parameters:

- laden mass is 1 825 kg;
- total weight is 2 500;
- wind (air) shape factor is 0.42 N·s$^2$/m$^2$;
- the dynamic radius of the wheel is 0.377 m;
- the moment inertia of the wheel is 2.8 kg·m$^2$;
- moment inertia of rotating masses reduced to the flywheel is 0.36 kg·m$^2$;
- maximum engine power is 75.8 kW at 4 000 rpm;
- load on the rear axle at full loading is 1 235 kg;
- maximum torque of the engine is 159.8 N·m.

The maximum gradient overcome by the automobile with higher cross-country capability should be at least 35% when the grip coefficient is 0.75. This value is used under limiting conditions on the right-hand side. It follows that the preliminary gear reduction ratio in the first gear is not less than 3.45.

Since the coefficient of the road grip of a tyre is assumed to be 0.75, the upper bound of gear reduction ratio in the first gear should not exceed 4.5. Then, the power range for the upper and lower bounds will be the variation pitch of 0.1.

For preliminary calculations, the variation range of the power consumption of the automobile running on earth and asphalt roads should be determined.

Power consumption reaches the maximum at the maximum automobile speed, load-carrying capacity and under poor road conditions.

Maximum automobile speed may be achieved under various conditions if the utilization factor of engine power in each gearing is high.

If the utilization factor of engine power is assumed to be 0.85 for all gears, average density values for a series of gear reduction ratios may be obtained.

The density of a series of gear ratios depends on the range of power consumption by the automobile operating under specified road surface conditions.

When the density of a series is *constant*, the average engine power in speeding up will be the highest if the time of using the stages is the same.

The total road resistance is assumed to be $\psi = 0.30$ ... 0.45 and is changed by the step 0.01.

The number of gearings may be found from the logarithmic ratio of power consumption ranges to the mean logarithmic value of hyperbolic series. The value of each gearing varies by a particular step and is checked for being an optimal value.

Constant gear reduction ratio $u_{const}$ is chosen simultaneously with the higher gear ratio $u_{hg}$ of the gearbox:

- if $u_{hg} = 1$ (*direct gear*), then $u_{const} = u_{T\,\min}$;
- if $u_{hg} < 1$ (*overdrive gear*), then $u_{const} = \dfrac{u_{T\min}}{u_{hg}}$.

Four-wheel drive vehicles have either single or double reduction gearbox.

Higher gear was taken into account together with the constant gear reduction ratio and chosen depending on working conditions.

The low gear in the gearbox is checked by the condition of providing the maximum gear reduction ratio $u_{gb}$:

$$u_{gb} = \frac{u_{T_{\max}}}{u_{fg} u_{mg} u_{wrg} u_{fd}},$$

where: $u_{fg}$ is the reduction ratios of first gears; $u_{mg}$ is the reduction ratios of the main gear; $u_{wrg}$ is the reduction ratios of wheel reduction gear, $u_{fd}$ is the reduction ratios of final drive.

Analytically expressed restrictions have non-linear dependences. The obtained functions are checked for stability to solve the problem of optimality. As a result, the global functional minimum is obtained on the number of variable iterations for each gear.

The table below shows the results obtained in optimizing gear reduction ratios of the automobile taking into account road conditions.

Optimization results show that:

- the torque of the engine should be increased from 159.8 to 210 N·m;
- the power of the engine should be increased from 75.8 to 80 kW;
- the number of gears should reach five.

On the basis of the above introduced data it may be concluded that the considered approach to complex computer-aided analysis of gear reduction ratios allows us to determine the optimal parameters of automobile gears more objectively than by using widely known methods of calculating gear reduction ratios.

The optimality criterion of braking system parameters is relative braking power:

$$f\left(J_\tau\right) = 1 - \frac{J_\tau}{\sum T} \to 0, \tag{3}$$

where: $J_\tau$ is braking power; $\sum T$ is the total kinetic energy of components:

- $T_{a\,x} = \dfrac{m_a \dot{x}^2}{2}$ is the power of the automobile moving translationally along the axis $x$ (where: $m_a$ is the mass of the automobile; );
- $T_{cm\,z} = \dfrac{m_{cm} \dot{z}_{cm}^2}{2}$ is the power of the vertical movements of the cushioned mass of the automobile (where: $m_{cm}$ is the cushioned mass of the automobile; $\dot{z}_{cm}$ is the vertical speed of the cushioned mass);

Results obtained in optimizing gear reduction ratios of the automobile taking into account road conditions

| Indices | Calculation results | | |
|---|---|---|---|
| | Current | Optimal | |
| | Road conditions | | |
| | Asphalt roads | Asphalt roads | Earth roads |
| Gear reduction ratio of the main gear | 4.625 | 4.540 | 4.890 |
| Gear reduction ratio of the first gear | 3.780 | 4.190 | 4.390 |
| Thrust on the wheels in the first gear, kN | 7.592 | 7.846 | 9.097 |
| Angle of gradient, degrees | 31 | 33 | 32 |
| Functional value | – | 0.610 | 0.530 |
| Gear reduction ratio of the second gear | 2.640 | 2.310 | 2.670 |
| Functional value | – | 6.502 | 1.060 |
| Gear reduction ratio of the third gear | 1.580 | 1.420 | 1.580 |
| Acceleration time, $t_{400}$ and $t_{1000}$, sec | 28 and 52 | 24 and 46 | 29 and 54 |
| Functional value | – | 6.510 | 5.310 |

- $T_{ucm\,z} = \dfrac{m_{ucm}\dot{z}_{ucm}^2}{2}$ is the power of the vertical movements of the uncushioned mass of the automobile (where: $m_{ucm}$ is the uncushioned mass of the automobile; $\dot{z}_{ucm}$ is the vertical speed of the uncushioned mass);
- $T_w = \sum_{i=1}^{n} \dfrac{J_w \dot{\varphi}_w^2}{2}$ is the power of the rotating automobile wheels (where: $J_w$ is the inertia moment of the wheel; $\dot{\varphi}_w$ is the rotating speed of the wheel; $n$ is the number of wheels).

When calculating braking power, a braking distance of automobile equivalent braking on the horizontal road with the initial automobile braking speed needs to be evaluated (Дьяков 2003; Тарасик 2006). The value of braking distance should not exceed the admissible value:

$$s_{\tau\,eq} < \left[ s_{\tau\,d} \right],$$

where: $[s_{\tau\,d}]$ is an admissible value of the design parameter of braking distance (specified by *ГОСТ Р 41.13-Н-99 – State Standard of the Russian Federation* and by other International Standards).

In this case, the following conditions should be satisfied (Дьяков 2003; Тарасик 2006):

- braking acceleration should exceed the admissible value $[j_\tau]$:

  $$j_\tau \ge \left[ j_\tau \right];$$

- the value of steady deceleration $j_{decel}$ should not exceed admissible value $[j_{decel}]$:

  $$j_{decel} \le \left[ j_{decel} \right];$$

- maximum rate of braking mechanism cooling should be maintained as:

  $$\left[ \Delta t \right] \ge \frac{\ln T_2'' - \ln T_1'}{\tau_{02} - \tau_{01}},$$

  where: $T_1'$ is the initial temperature of braking mechanism reduced with respect to the ambient temperature; $T_2''$ is the final temperature of braking mechanism reduced with respect to the ambient temperature; $\tau_{01}$ is the current time of started cooling, sec; $\tau_{02}$ is the current time of completed cooling, sec;
- the relationship between pressure in the front ($p_1$) and back ($p_2$) coolant loops of braking system should be $p_1 \approx p_2$ at full and partial loading;
- grip coefficient $\varphi_x$ for the axles under full and partial load and the coefficient of braking $\left( z_\tau = \dfrac{j_{decel}}{g} \right)$ were in the range of the International Standard;
- frictional force should be smaller than the admissible one;
- the coefficient of brake efficiency should exceed the admissible value $[k_{\tau\,ef}]$:

  $$k_{\tau\,ef} \ge \left[ k_{\tau\,ef} \right].$$

If calculations are made for an automobile moving along the horizontal road section with low initial speed (not exceeding 80 km/h), grade resistance $F_{gr}$ and air resistance $F_{ar}$ may be neglected.

Braking distance $s_\tau$ is assigned as the sum of elementary braking paths of the automobile at time $\Delta t$ assuming its deceleration to be constant. Consequently, the parameters of braking system are determined. It is shown that calculations are rather accurate, when $\Delta t = 0.01$ sec.

In calculating stopping distance, deceleration is assumed to be growing non-uniformly for 0.5 sec. Subsequently, deceleration starts at the right time when the need arises. Since the time of deceleration increase is very short, the error would be small and could be neglected. The time $t_\tau + 0.5t_n$ of decreasing automobile speed from $v_0$ (the initial automobile braking speed) to zero, when deceleration is $j_{\tau\,\max}$, may be expressed as:

$$t_\tau + 0.5t_n = \frac{v_0}{j_\tau}.$$

## 6. Conclusions

Given the objective function and constraints, automobile parameters may be optimized either in general or depending on a particular level of complexity.

At level 2, all other systems, units and parts may be considered. For this purpose, a particular optimization method should be chosen and taking into account a nonlinear character of constraints, a method of penalty functions including logarithmic penalty should be used.

The function is checked for stability of solution. When the global minimum is obtained, all parameters to be used in designing automobiles or upgrading the automobile are fixed (for example, write to file or printed out).

When manufactured and maintained, the automobile should meet the requirements imposed by customers and agree to demands for minimal power losses and labour expenditure. These criteria are aimed at using the automobile when the problem of optimization is under discussion.

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