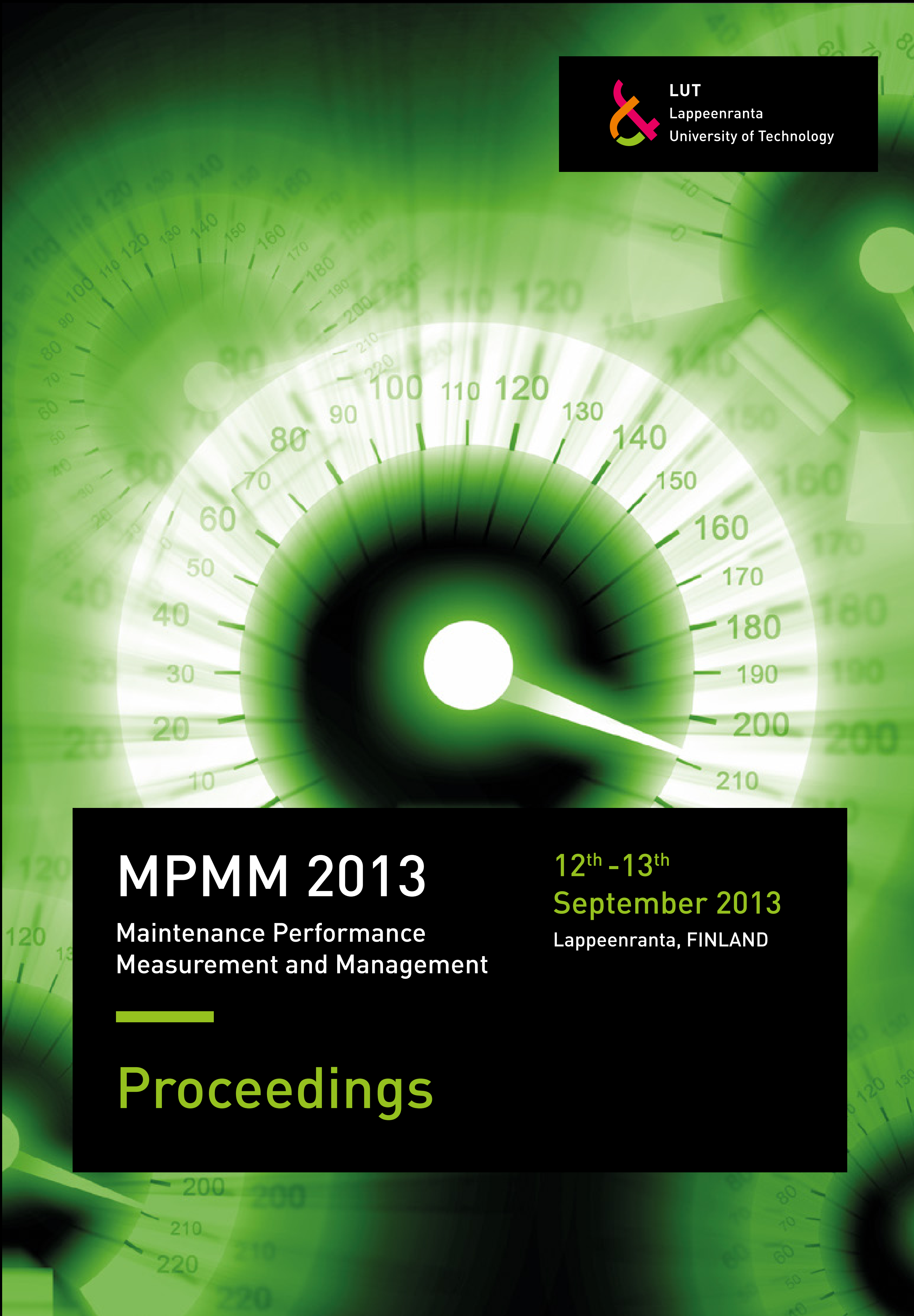

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"Cloud" services for improving production efficiency of industrial enterprises

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Abstract

The paper describes research and development of software platform for optimal operation planning of industrial enterprises using "cloud" computing technology. This work is a part of long-term activity carried out by Petrozavodsk State University (PetrSU) in the field of scientific research, software development and customer projects for enterprises of pulp-and-paper and forestry industry. The platform includes advanced mathematical models and optimization algorithms developed by IT-park of PetrSU and is used to develop services for solving planning tasks at different types of enterprises: corrugated packaging production, hardwood sawmills, plywood mills, paper production, as well as transportation companies (or units). Screenshots and mathematical model are provided only for "Sawmill" service, but the procedure is quite similar also for other services.

Key words: "cloud" platform, optimal planning, "cloud" service

1 Introduction

Similarity of production processes on different enterprises allows developing a common platform for production planning for these enterprises. However, using a large amount of locally installed software on geographically distributed enterprises results in additional time and costs needed for the software maintenance. One of the approaches to reduce the maintenance costs is to use "cloud" computing technology. For the implementation of this technology for the production planning tasks it is useful to develop a software platform, which includes a wide range of functional possibilities for software implementation, maintenance, and solving process optimization tasks.

The paper presents description of innovative production planning platform based on "cloud" computing technology. The platform consists of software modules library with optimization algorithms, as well as auxiliary services. Using the platform, several "cloud" services for production planning and management at different types of enterprises have been developed, mainly in the pulp-and-paper and forestry sectors. Brief descriptions of some of the developed services are provided, including main features of process technology, main functions, economic benefits, and reference lists.

The use of the services allows the mills to noticeably improve efficiency and productivity: reduce the material losses (by 1-3%), to increase the equipment uptime by 3-4%, and shorten the production planning time (by 1.5 – 2 times). Altogether this leads to saving of several hundred thousands euro per year at each mill. The use of the services also allows customer specialists to model and compare side-by-side various scenarios of production and procurement, and select best and justified scenario, thus improving control over production.

2 Cooperation of IT-park of PetrSU with industrial enterprises and organizations of Finland and Russia

Development of software systems for improving production efficiency of industrial enterprises is a part of long-term and diverse activity carried out at PetrSU. A distinctive feature of IT-park of PetrSU is automation of non-typical and complex business-processes by exploiting mathematical methods to solve complex problems such as optimizing planning and resource allocation, trim, and composition. IT-park delivers a broad range of IT services to support manufacturing companies, including:

- Creating mathematical models for solution of complex enterprise management problems;
- Designing algorithms and software packages for optimization problems solution;
- Developing, commissioning and maintaining management information and process control systems;
- Providing management consulting.

IT-park of PetrSU was founded in 2005 and brought together 23 units of the university within 3 departments – ICT, system engineering, and education technologies in ICT. The total number of staff is about 400 people.

The platform development is based on long-term cooperation experience with a wide range of Russian manufacturing enterprises, mainly of the pulp-and-paper and forestry industries, which has been actively developing since 1982. Among the customers are Arkhangelsk, Bratsk, Kiev, Kotlas, Kondopoga, Segezha and Svetogorsk pulp-and-paper mills (which are among 10 largest pulp-and-paper mills in CIS), as well as many other smaller industrial enterprises. Since 1982 more than 150 custom software systems (including since 2005 -- more than 70 systems) have been delivered to industrial enterprises and organizations of Finland, Russia and CIS. Since 2011 this activity has been further intensified by establishment of Opti-Soft Ltd (http://opti-soft.ru) – a small innovative company, which is 100% owned by PetrSU.

Also important expertise was gained in cooperation with industrial customers and partners in Finland, including Metso Corporation (since 1993), Outotec Oy (since 2008), Nokia Research Center (since 2007) and other smaller companies. The joint activities include: mathematical models and software for industrial automation and process control, scientific research, organization of conferences and seminars, and training of specialists.

3 The "cloud" platform for optimal planning

Cloud services are widely used and written in scientific articles. Cloud Computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services (Armbrust and Fox, 2009). Numerous IT vendors are promising to offer computation, storage and application hosting services. Currently, expert developers are required to implement cloud services (Buyya et. al., 2010). Cloud-based applications and new capabilities are emerging daily and bringing with them lower cost of entry, pay-for-use models, greater scalability, improved performance, and improved business continuity (Jamsa, 2011). Cloud computing can help small and medium business to lower their IT costs as the supported functionalities of software are no longer fixed or locked to the underlying infrastructure. This offers tremendous automation opportunities in a variety of computing domains (Wang et. al., 2012).

Practical implementation of "cloud" computing in solving problems of optimal production planning requires development of a platform with a wide range of functionality to simplify and speed up software implementation and maintenance, as well as solution of optimization problems arising at industrial enterprises.

The main components of the platform include (see Fig.1):

- Applications server, whose main part is business logic of software services, describing relevant subject areas,
- Optimization server, including the library of modules for solution of optimization problems,
- File server, managing storing and joint access to files of various types,
- Database server, managing storing, filling and changing data, as well as for providing information in response to the application server requests,
- Audit server, managing complex monitoring of activity of various modules.

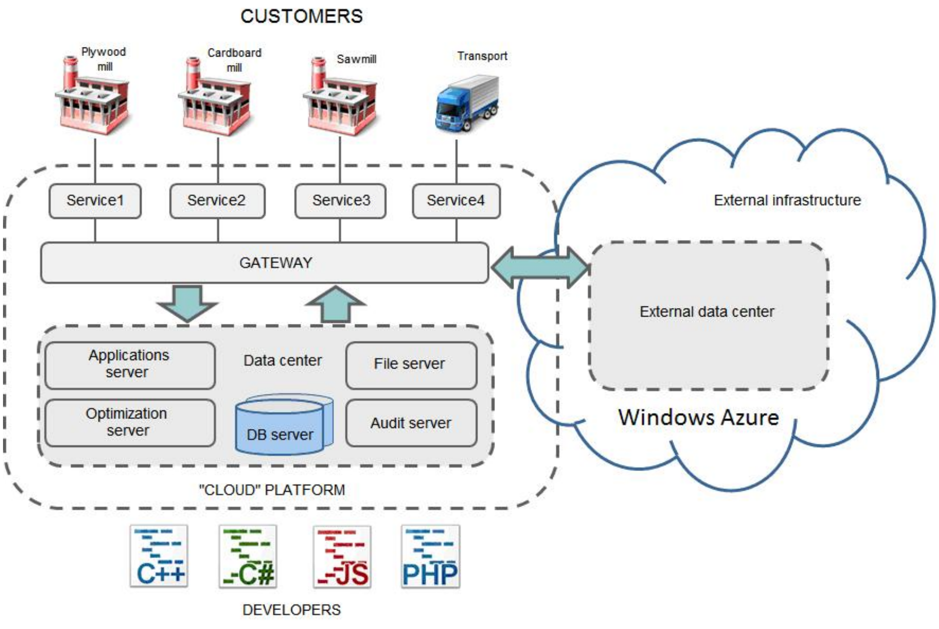

Figure 1. The main components of the platform

All platform components are integrated into MS Visual Studio.NET and can be freely and uniformly used together with standard methods and components of MS Visual Studio.

On the basis of the platform, "cloud" services for optimal planning and management of complex production processes of industrial enterprises are developed. This is possible and efficient, because such services typically use quite similar set of menus, forms, tables, dialog boxes and other components, as well as optimization algorithms.

The main component of user interface of each "cloud" service is a web browser, which generates visual representation of the product and exchanges data via "gateway" layer with servers of the platform (typically using encrypted channel to protect the customer and the Platform from unauthorized access).

The optimization algorithms are based on earlier developed in PetrSU mathematical models and methods for solving a wide range of optimization problems. In particular, they cover operations of cutting, collecting and transporting materials, quite typical in planning and management of pulp-and-paper and forestry industry enterprises (Kuznetsov et. al., 2008). Several optimality criteria are used when solving optimization problems – profit maximization, minimization of the production costs and resource consumption, and other, as well as mixed criteria.

The specialized library ("universal" solver") is one of the main distinctive features of the platform (Kuznetsov et. al., 2008). It has been developed based on 30 years of experience in customer projects for companies and enterprises of Russia, and Finland. Algorithms for effective solution of complicated cutting problems, including linear and nonlinear optimization problems, high-dimension problems, problems with combined criteria, etc. are implemented based on the versatile solver. The library also includes a special module ("matrix constructor") for increasing efficiency of constructing, storing and using constraints matrix.

The hardware is currently provided by own data-center of IT-park, but can also be moved or combined with external infrastructure, e.g. Windows Azure or other.

4 "Cloud" services for optimal planning at industrial enterprises

On the basis of the platform, a spectrum of specialized "cloud" services have been developed for optimal management of several types of enterprises, including the following:

– "Corrugated cardboard" – for corrugated cardboard plants operation
– "Sawmill" – for sawmills operation
– "Loading" – for optimal loading of transportation facilities (trucks, trains and ships)
– "Trim optimization" – for trim optimization during paper machines operation
– "Plywood" – for plywood mills operation

Development of each service is based on quite deep study of the process technology, otherwise planning results would not be efficient (and sometimes even not useful). Integration of the services into existing ICT ecosystem at Customer enterprises is possible.

Description of each service follows. Due to lack of space, screenshots and mathematical model are provided only for "Sawmill" service, but demos are available at http://opti-soft.ru/

4.1 “Corrugated cardboard” service

The line of corrugated cardboard is cut into rectangular pieces at the speed of 160m/min. The pieces are used for making boxes. The task of the mill management is to ensure the production of required number of boxes made of several rectangles of different size. As the number of boxes types exceeds 100 per week, and the number of boxes of each type is less than 1000, the material losses increase to 5-6%, planning time – to several hours, etc. The service uses mathematical methods and optimization algorithms to decrease the material losses and planning time, and increase the equipment uptime.

The target of the service – production of balanced amounts of rectangles of cardboard for making boxes with minimal material losses, considering the production capacity and re-tuning time of equipment, order scheduling and priorities.

The main functions of the service include:

- Generation of all feasible cutting orders according to specified types of boxes
- Finding the cutting order, which ensures production of required number of boxes, including the warehouse stock
- Production optimization according to material losses
- Monthly planning of plant operation (target figures may be loaded from other systems)
- Price calculation for each type of box
- Tracking the effect of each additional type of box on total plant material losses
- Documentation, reporting and archiving
- Integration with other systems, including accounting systems, ERP systems, process control systems (e.g., BHS, Dücker, Signode) and other.

The "local" software system and the "cloud" service have been *successfully installed* at 15 enterprises, including the following main ones:

- OJS "Arkhangelsk pulp-and-paper mill" (Arkhangelsk, Russia)
- OJS "Kiev pulp-and-paper mill" (Obuhov, Ukraine)
- "Naberejno-Chelninsky cardboard-and-paper mill" Ltd. (Naberejnye-Chelny, Russia)
- CJS "Gotek" (Zheleznogorsk, Russia),
- "Nizhkarton" Ltd. (Nijny Novgorod, Russia),

The use of the service enabled the mills to reduce the material losses from 5-6% to 2-4%, which amounts to saving of several hundred thousand euro per year, and also has noticeably reduced the production planning time – by 1.5 – 2 times.

Consideration of re-tuning of the finishing equipment while planning the cutting equipment operation remarkably reduces the number and duration of finishing equipment downtime periods. As a result, the total production line uptime is increased by 3-4%.

In 2008 the "local" system received Certificate №№1640 of the Foundation of algorithms and software of the Russian Federal Agency for Education. In 2012 the web-based service was registered by Russian Federal Service for Intellectual Property, Patents and Trademarks (Certificate №2011618457). In 2009 the System has won **Golden medal** in nomination "The best innovative and R&D project of the year" of St.-Petersburg Technical Fair.

4.2 "Sawmill" service

The aim of the sawing process consists in processing round wood into sawn lumber, as well as technological wood chips. Typically a sawmill receives logs of various grades and diameters and sawn lumber is also divided according to sorts and sizes. The problem of sawing patterns calculation consists in specification of sizes and number of lumber to be cut from each log of given quality, length and diameter. As a rule, monthly plans cover more than 10 grade groups of logs and the number of produced sawn lumber grades is 50 or even 100.

The plan contains quantity and size-qualitative structure of logs to be sawn and the lumber produced by applying each sawing pattern, taking into account all features, limitations and parameters of process equipment, as well as of raw material and production orders. The use of the service also improves the efficiency of calculating and correcting the operational plans.

The target of the service – with the use of advanced mathematical models and optimization algorithms of own development to solve a series of sawmill operation planning tasks for any number of orders and any configuration of process equipment.

The main functions of the service include:

- Calculation and selection of cutting patterns
- Calculation of optimal plan, ensuring production of given specification of lumber from available (or expected) wood – either by maximal profit from the lumber, or by minimal use of wood
- Calculation of profitability of new orders in combination with existing production plan, and with possible new orders
- Calculation of optimal limits for log types (diameter groups) for sorting lines
- Calculation of optimal calendar plan in order to maximize the use drying and finishing equipment

The developed mathematical model takes into account all known essential features, limitations and parameters of process equipment, of raw material and production orders.

Parameters of equipment:

- The number and saw cut width for saws of 1st and 2nd row for each saw bench
- Relation between maximal diameter of log, which can be cut on the saw bench, from maximal height of the cut and maximal width of the cutting pattern
- Productivity of saw bench per shift depending of diameter and length of logs
- Minimal width of the two-edged cant (separate for each log diameter), because smaller width leads to increased waste
- Minimal production volume per each cutting pattern, because each retuning of saw bench leads to waste of time
- Minimal width of central part of the cant, minimal difference between width of cant and side part
- Maximal width of side part, maximal number and width of side boards, maximal number of different types of sawn timber in the cutting pattern
- Many other, depending of the sawmill equipment parameters.

Parameters of orders:

- Minimal and maximal production volumes for each type of sawn lumber

- Minimal and maximal length of lumber, and cutting steps (which reduces the output)
- Required moisture content after drying
- Quality of lumber (A, B, C and other)
- Priority of an order (to ensure delivery performance)
- Requirements regarding positioning of lumber relative to log axis:
  - in cant part only, i.e. only from two-edged cant
  - in side part only
  - in central part
  - 2 Ex-Log, i.e. 2 boards in central part (without central board)
  - 2 Ex-Log not side board, i.e. 2 boards in central part with other boards in the two-edged cant
  - 3 Ex-Log, 4 Ex-Log, 5 Ex-Log, 6 Ex-Log – similarly
  - Not in the center
  - 2,4,6 Ex-Log, i.e. in central part, without central board (but for large diameters (e.g. over 30cm) this constraint can be skipped)
  - Maximal share of lumber from side part (for Ex-Log; e.g. not more than 20%).

The system has friendly and flexible user interface and can be easily modified to handle new customer-specific requirements.

The use of the system allows to increase overall mill productivity, output of high-quality grades of lumber and better matching the production specification. Overall increase of profitability – by 1-2%. More details are provided in next section.

The efficiency of the system has been confirmed during 2011-2013 on real production data of 4 sawmills in North-western Russia: OJS «Medvezhegorsky sawmill», OJS «Segezhsky sawmill», OJS «Sokolsky DOK», CJS «Solomensky sawmill».

In 2012 the System was registered by Russian Federal Service for Intellectual Property, Patents and Trademarks (Certificate №2010617003). Also in 2012 the System has won **Silver medal** in nomination "The best innovative and R&D project of the year" of St.-Petersburg Technical Fair.

4.3 “Loading” service

The paper rolls are transported in train carriages, trucks, and ships. The vehicle must be loaded according to strict rules, the violation of which results in quality degradation and customer complaints. As the number of different types of rolls grows, and vehicle internal geometry becomes complicated, the order or loading of rolls into a vehicle may become relevant. As a result, the vehicle may carry less load than it could. The order of loading of rolls into a vehicle depends on vehicle geometry (the center of the roof of a railroad carriage is always higher than the walls), size and location of the gates (front or side), load balancing, etc. The number of possible combinations of rolls is inconceivable.

The service uses mathematical methods and different combinatorial, linear, dynamic and integer optimization algorithms to load more cargo into a set of vehicles, decrease the number of vehicles used, as well as to provide graphic presentation of cargo inside the vehicle.

The *use of the service* in many cases enables to increase by 5-10% the total weight of paper rolls loaded in a transportation vehicle. This enables to use less number of railroad carriages, trucks and containers. Also the planning time is noticeably reduced – by 1.5 – 2 times.

The software system had been *successfully installed* at OJS "Bratsk pulp-and-board mill", OJS "Kondopoga pulp-and-paper mill", OJS "Kotlas pulp-and-paper mill" (all – in Russia).

In 2008 the "local" system received Certificate №№1644 of the Foundation of algorithms and software of the Russian Federal Agency for Education. In 2013 the web-based service will be registered by Russian Federal Service for Intellectual Property, Patents and Trademarks.

4.4 “Trim optimization” service

Roll sets are produced by the winder from the parent reel. The “trim” (the width of the parent reel exceeding the width of the roll set) is a waste. With parent reel widths up to 10m, roll widths down to 50cm, and production orders including many different roll widths, there are thousands of ways to cut the parent reel to obtain the required rolls. Usually, there are 3-4 PM with different speed, parent reel width and density, and possibly paper quality. The production targets are set for entire mill, and paper grade change results in bad paper and lowers the total mill production. The service uses mathematical methods and optimization algorithms to plan the operation of several PMs to meet the production targets and minimize waste. Also the planning is simplified for the operators.

The target of the service – calculating the optimal distribution of orders between several paper machines for the purposes of increasing the productivity in given conditions, closest matching of production targets, decreasing of trim losses, decreasing of amount of down-graded paper.

The automation system has been installed at OJS 'Kondopoga' – one of 10 largest paper mills in Russia. The use of the system results in saving of 1.2% of paper per year. Considering the tons-per-year of paper production from a modern paper machine, even savings of 0.5% make this type of process control economically profitable. The other significant advantage is reduced time for production planning.

In 2008 the "local" system received Certificate №№1641 of the Foundation of algorithms and software of the Russian Federal Agency for Education.

4.5 “Plywood” service

Plywood is made from thin sheets of wood veneer (plies), which vary in thickness 2.5-4mm. Usually, 3, 5 or 7 plies of dimension 1.2×2.4m are glued together at right angles to each other to form the plywood panel, which can then be refinished. 4-5 quality grades of panels exist.

With hundreds of production orders received, thousands of plies already available (as well as timber logs for making new plies, if needed), there are thousands of feasible ways to obtain the sheets of required quality. Due to various limitations on the equipment operation, the planning must be made very carefully to meet the production and economical targets. The service uses mathematical methods and optimization algorithms to increase production by cost or volume (on average, by +1.5% per month) by using existing plies more efficiently, as well as to simplify the planning procedures for the operators.

In 2008 the "local" system received Certificate №№1642 of the Foundation of algorithms and software of the Russian Federal Agency for Education. In 2013 the web-based service will be registered by Russian Federal Service for Intellectual Property, Patents and Trademarks.

5 The mathematical model and the service for sawmill optimization

Due to lack of space, screenshots and mathematical model are provided only for "Sawmill" service, but the procedure is quite similar also for other services, presented in this paper.

5.1 The main model

Initial data:

L – set of timbers (enumerated)
W – set of sorting groups and kinds of wood (enumerated)
M – set of sawing lines (enumerated)
C – generated set of sawing patterns (Tyukina, Y. and Makarova, N. (1988))
$d_{i,j}$ – share of timber $i \in L$ in sawing pattern $j \in C$. $d_{i,j} \in [0,1]$
$g_{w,j}$ – 1, if sawing pattern $j \in C$ involves wood kind $w \in W$, 0 otherwise
$h_{m,j}$ – 1, if sawing pattern $j \in C$ involves sawing line $m \in M$, 0 otherwise
$v^d{}_m$ – minimal total wood volume, sawn at sawing line $m \in M$
$v^u{}_m$ – maximal total wood volume, sawn at sawing line $m \in M$
r – minimal sawing pattern volume (only for selected patterns)
$v^s{}_w$ – volume of wood kind $w \in W$ at the warehouse
$v^p{}_j$ – minimal production volume of timber $i \in L$
$v^q{}_j$ – maximal production volume of timber $i \in L$
z_i – unit penalty for deviation from constraint on minimal production of timber $i \in L$
y_m – unit penalty for deviation from constraint on minimal sawing volume at line $m \in M$

Unknowns:

x_j – total wood volume, sawn using sawing pattern $j \in C$
$f^l{}_i$ – deviation from constraint on minimal production volume of timber $i \in L$
$f^u{}_i$ – deviation from constraint on maximal production volume of timber $i \in L$
$f^m{}_m$ – deviation from constraint on minimal sawing volume of sawing line $m \in M$
$f^r{}_m$ – deviation from constraint of maximal sawing volume of sawing line $m \in M$

Then the main optimization problem looks as follows:

$$\begin{aligned}
&\sum_{j \in C} \sum_{i \in L} d_{i,j} x_j \to \max \\
&v^p{}_i \le \sum_{j \in C} d_{i,j} x_j + z_i (f_i^u - f_i^l) \le v^q{}_i, \quad i \in L \\
&\sum_{j \in C} g_{w,j} x_j \le v_w{}^s, \quad w \in W \qquad\qquad (*) \\
&v^d{}_m \le \sum_{j \in C} h_{m,j} x_j + y_m (f^r{}_m - f^m{}_m) \le v^u{}_m, \quad m \in M \\
&x_j \in \{0\} \cup [r, +\infty)
\end{aligned}$$

The main unknown variables are volumes of logs to be cut according to each sawing pattern, which uniquely defines the order and places of cuts, as well as thickness, width and length of sawn lumber produced. The main solution algorithm of the problem (*) is presented on Fig.2, where v – vector of dual estimates for each constraint of the problem (*), A_j – j-th column of main matrix (Fig.3), c_j – j-th coefficient of goal function of the problem (*) $c_j = \sum_{i \in L} d_{i,j}$, $j \in C$.

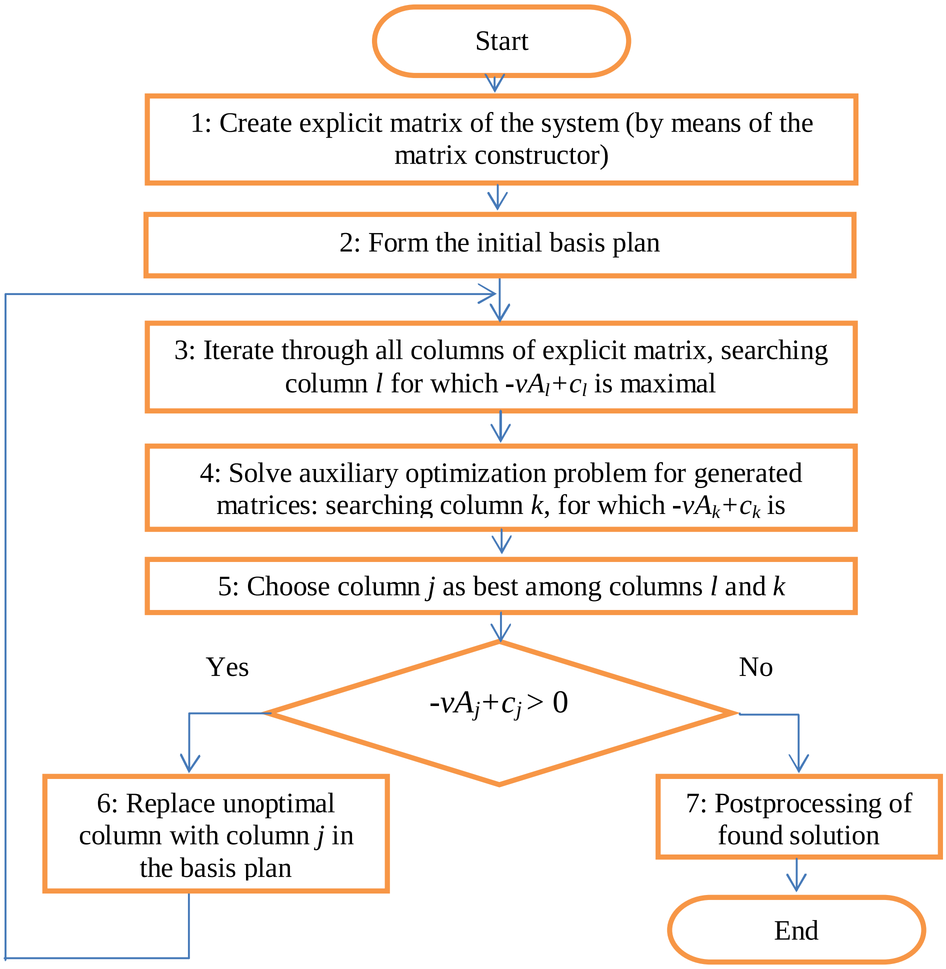

Figure 2. The main solution algorithm for sawmill optimization problem

The structure of the main matrix of problem (*) is presented on Figure 3 below. IT-park research and project experience shows that constraints matrices in practical optimization problems typically have large dimension and distinctive block structure. Therefore, a special data structure was developed («the matrix designer»), which increases the efficiency of storing and using explicit constraints matrix by splitting it into sub-matrices.

It should be noted that set of all sawing patterns C only rarely can be provided explicitly, because there can be millions of feasible combinations of timbers, sorting groups, kinds of wood and sawing lines, each of which would've been a column in corresponding matrix C. Instead, the new column to be added to the basis plan at step 6 of algorithm on Fig. 2 is computed using solution of auxiliary optimization problem (step 4 of algorithm on Fig. 2).

On Fig.3: MDS – square diagonal matrix with equal elements on main diagonal (typically, 1 or -1), MS – any matrix with all elements equal, M – any other matrix.

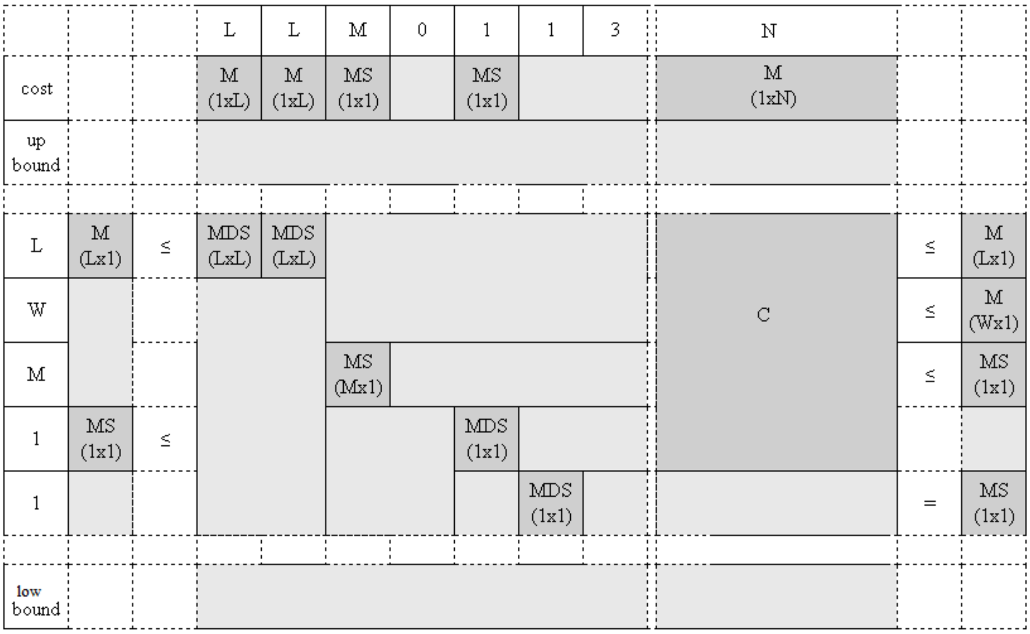

Figure 3. The main matrix of the problem (*)

The main method for solution of optimization problems is the columns generation method (Dantzig, 1963; Kantorovich and Gorstko, 1968). Its major difference from other methods is that optimality of a solution is checked not by using explicit matrix, but by solving an auxiliary optimization problem. The standard columns generation method was improved to efficiently handle constraints that are typical for practical optimization problems – upper and lower bounds on production volumes, several identical production units, proportional dependence between variables, etc.

5.2 The auxiliary optimization problem

Initial data

N – set of timbers;
W – set of sorting groups and kinds of wood;
t_j, w_j – thickness and width of timber $j \in N$ accordingly, in mm;
b_j – sign that timber is basic (1 – basic, 0 – otherwise), $j \in N$;
u^b – minimal share of volume of basic timbers, $u^b \in [0,1]$
u^s_j – maximal share of timber $j \in N$ from side part, $u^s_j \in [0,1]$
v^l_j – dual estimate of timber $j \in N$;
v^w – dual estimate of current wood $w \in W$;
v^b – dual estimate of constraint on the minimum share of basic timbers;
v^s_j – dual estimates of constraints on the maximum share for timber from side part, $j \in N$;
V^w – volume of a log of wood $w \in W$;
c^w – cost of 1 m^3 of wood $w \in W$;
c^l_j – price of 1 m^3 of timber $j \in N$;
s_1, s_2 – thicknesses of saws at the first and second pass accordingly.

Unknowns:

P^b – set of positions for placement of timber in cant part of a log.

P^s – set of positions for placement of timber in side part at the first pass.

z^b_p – index of timber in p-th position in cant part, $p \in P^b$, $z^b_p \in N$

y^b_p – distance from the center of sawing pattern to timber z^b_p in cant part (in mm). For central timber of the pattern $y^b_p = -\frac{t_{z^b_p}}{2}$.

l^b_p – length of timber in position $p \in P^b$ in cant part

z^s_p, y^s_p, and l^s_p – defined for side part similarly;

W^b – width of received two-edged cant: $W^b = \max_{p \in P^b} \{ w_{z^b_p} \}$

W^c – width of central part of two-edged cant: $W^c = 2 \max_{p \in P^b} \{ y^b_p + t_{z^b_p} \mid w_{z^b_p} = W^b \}$

q_p – 1, if $y^b_p = -\frac{t_{z^b_p}}{2}$, 2 otherwise ($p \in P^b$)

g_p – 0, if $w_{z^b_p} = W^b$, 1 otherwise ($p \in P^b$)

Constraints:

- Timber belongs to group $D_{2 \times k}$ (requirement "2 *k* Ex Log", $k \in \{1,2,3\}$):

$$\forall\, j \in D_{2\times k} \Rightarrow \begin{cases} y^b_1 = \frac{s_1}{2}, \quad z^b_1 = z^b_2 = \ldots z^b_k = j, \\ \sum_{p \in P^b,\, z^b_p = j} q_p = 2k. \end{cases}$$

- Timber belongs to group D_{nm} (requirement "Not in the center", e.g., for Japanese timber “Mabashira”):

$$\forall\, p : z^b_p \in D_{nm} \Rightarrow y^p_b \neq \frac{s_1}{2} \; u \; y^p_b \neq -\frac{t_{z^b_p}}{2}.$$

- The maximum total width of side part in cant part is not more than W^{sm}:

$$\max_{p \in P^b} \{ y^b_p + t_{z^b_p} \mid w_{z^b_p} < W^b \} - \min_{p \in P^b} \{ y^b_p \mid w_{z^b_p} < W^b \} \leq W^{sm}.$$

- Thickness of each timber in side part in cant part is not more than t^{sm}:

$$\forall\, p \in P^b : w_{z^b_p} < W^b \Rightarrow t_{z^b_p} \leq t^{sm}.$$

- The total difference between cant part and side part is no less than D^{cs}:

$$W^b - \max_{p \in P^b} \{ w_{z^b_p} \mid w_{z^b_p} < W^b \} \geq 2D^{cs}.$$

- Other constraints.

These and other constraints are graphically illustrated on Fig. 4. In the service it is implemented as a form for input of corresponding parameters, which makes their meaning intuitively very clear for users with relevant technology background. More similar forms can be created for input of other parameters.

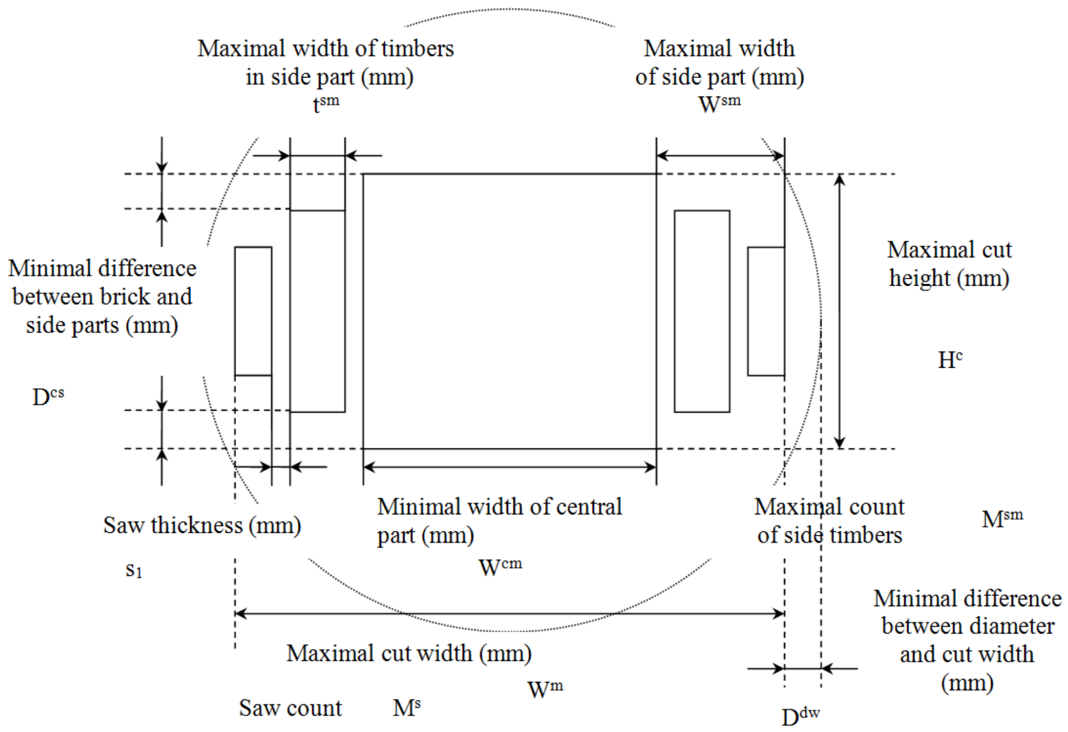

Figure 4. Graphical presentation of main sawing pattern parameters

Goal function:

$$\sum_{p\in P}\frac{l_p q_p t_{z_p} w_{z_p}}{V^w}\left(-v^l_{z_p}+1+v^b\left(u^b-b_{z_p}\right)+v^s_j\left(g_p-u^s_{z_p}\right)\right)+v^w+v^m\rightarrow \max .$$

This auxiliary optimization problem is solved in quite complicated way using dynamic programming (Bellman, 1957), but full description is beyond the limits of this paper. Formulation of all technology requirements and limitation in mathematical form, suitable for applying optimization methods, requires considerable effort and mathematical qualification.

5.3 User interface

This model and corresponding solution algorithms have been implemented in web service of optimal planning of sawmill operation. The service has been implemented using modern Kendo UI and Stimul Report components on ASP MVC 3 platform. One of the user forms is presented on Fig.5. The user interface can be modified to according to customer requirements.

5.4 Economical benefits from using the service

The economical benefits from using the service are summarized in Table 1. For each sawmill the values in "before" columns were obtained by existing optimization routines, and in "after" columns – by the service. Technical feasibility of all plans calculated by the service have been in every case confirmed by mill staff.

The first use case was to produce fixed specification of lumber from smaller volume of wood (material savings) during planning period equal to one month. The corresponding figures for each sawmill are averages for 4-10 months (depending on the mill). The use of the service allowed to increase the share of lumber (in raw wood) by 1.1-1.6 % (1.2% on average), and to decrease raw wood consumption by 1.2-2.5% (1.9% on average) during a month.

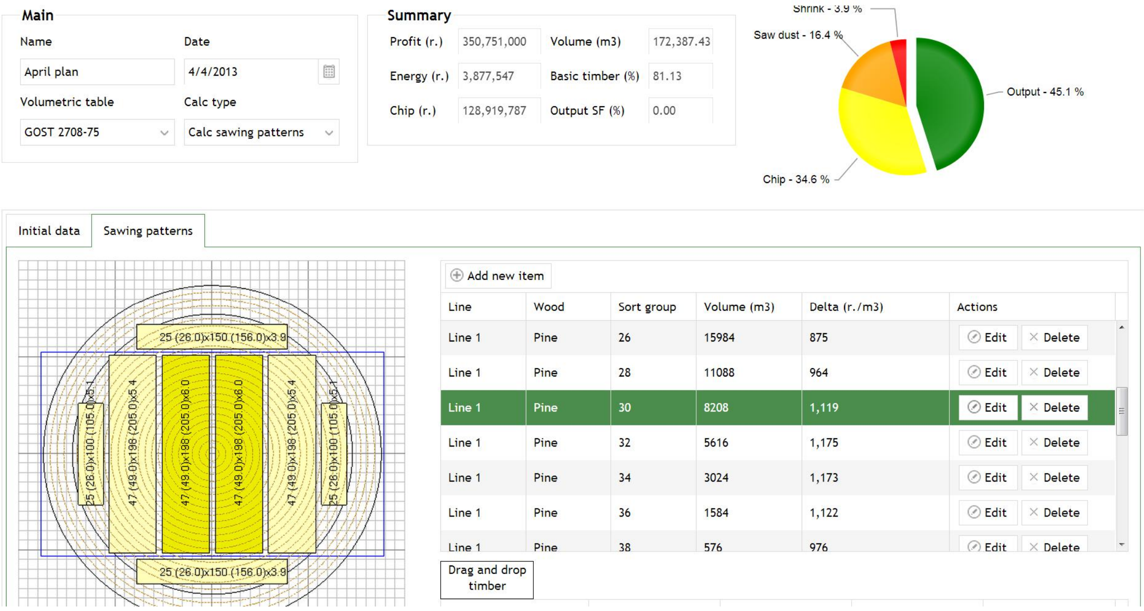

Figure 5. Graphical presentation of main sawing pattern parameters

The second use case was to find the most profitable production specification using all available wood during planning period equal to one month. For some types of lumber the production volumes were fixed (e.g., 1000 m^3), and for some – were given in limits (e.g., 800-1200 m^3). In this case the use of the service allowed to increase the "delta" (difference between the price of lumber and the cost of raw wood) by 1-1.5% (on average 1.1%) during a month. The absolute values of "delta" (in rubles) can not be published.

Another advantage of using the service is reduced time for calculating and correcting the plans – by 1.75-2 times every month. The additional "free" time can be used for more detailed analysis of mill operation. Overall, the payback period of the service is less than 3 months depending on orders portfolio and other specifics of the mill and planning period.

Russian sawmills seldom use optimization software by foreign providers, because it does not allow to take into account essential features of their production processes. However, authors are willing to compare optimization abilities of the service with similar optimization software.

Table 1. Summary of economical benefits from using the service

Company	**Share of lumber, before**	**Share of lumber, after**	**Wood consumption (m3), before**	**Wood consumption (m3), after**	**Increase of "delta"**	**Calculating plans (hours), before**	**Calculating plans (hours), after**
"Medvezhegorsky sawmill"	49.3%	50.4%	15 765	15 367	N/A	10	5
"Segezhsky sawmill"	45.0%	46.2%	18 194	17 976	N/A	6.5	3.5
"Sokolsky DOK"	46.4%	48.0%	16 294	15 996	N/A	8	4.5
"Solomensky sawmill"	48.3%	49.3%	22 096	21 642	1.10%	7.5	4
Average	47.3%	48.5%	18 087	17 745		8	4.25

6 Conclusion

The number of successfully implemented "cloud" projects for small, medium and large businesses is steadily growing. "Cloud" services are being offered by many IT companies, including Microsoft (Dynamics AX), 1C, SAP, Oracle, thus acknowledging the relevance of research and development in this area.

IT-park continues improvement of existing "cloud" services for optimal planning at industrial enterprises, presented in this paper, as well as develops new services. IT-park specialists are also ready to customize them to specific demands of each Customer. The use of unique mathematical models, methods and algorithms combined with modern software development platforms and methodologies enables IT-park specialists to offer products, which improve the productivity and profitability of key production processes of its Customers.

The use of the services enables the Customers to reduce material losses, increase the profitability, and also reduce the production planning time, which leads to significant economic benefits as has been confirmed by Customers.

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