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MASTER'S THESIS

Machining Workshop Reconstruction Project for the Manufacture of Solid Wood Furniture at the Arkhangelsk Plywood Factory Joint-Stock Company

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Abstract

It is proposed that the manufacture of solid wood furniture be organized in a reconstructed machining workshop of the Arkhangelsk Plywood Factory furniture plant in Novodvinsk.

Reconstruction involves installing modern and domestic equipment, to permit the efficient manufacture of either currently-produced furniture or new furniture types.

A bedroom set was chosen as the furniture of interest. The bedroom set consists of a double bed, a folding wardrobe, a chest of drawers and two bed-side tables. According to a market survey conducted in Arkhangelsk, Severodvinsk and Novodvinsk 156 sets of bedroom furniture should be produced to fill the market and meet the requirements of customers.

Capital investments of the proposed reconstruction in total come to 1350,000 rubles, with a net profit of 1400,000 rubles; payback period is 13,5 months. This means that the project is economically viable.

In the research section of the explanatory note, experiments to determine deformations emerging in glulam made from a combination of pine and spruce lamellas under conditions of variable humidity are described. Results indicate that the deformation of the uniform structure panel is less pronounced than that of the combined panel. The degree of deformation can be reduced when a protective coating is applied.

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Introduction

Background

The most prevalent piece of furniture of olden times might be considered the “banged-together” stool. However, manufacturing of furniture eventually expanded, and so did the skills of furniture-makers - leading to the creation of fine, almost weightless “Viennese” chairs.

Nowadays it is possible to buy furniture made of a variety of materials, and not only from wood. However, none of them can ever replace that esthetically pleasing perception of wood, which so strongly affects the senses of touch, vision, hearing, smell and taste.

Because of the existing tradition of furniture manufacture in our country, which has emerged under pressure from Western European countries, the mostly common used plate materials are particleboard, plywood, and fiberboard, including the saleable medium density fiberboard MDF. It is known that solid wood furniture takes the last place in the list, in spite of Russia’s huge timber resources, which make up about one third of all timber resources in the world.

Currently the primary material for the mass production of cabinet furniture is particleboard – a material that combines the necessary characteristics of construction material (large dimensions, stability of shape, sufficient strength and isotropy of properties along the plane of the board) - with a wide raw material base as the secondary raw material of sawmills, and modern synthetic adhesives. This thesis work proposes to prefer natural material over artificial.

The advantages of glulam panels as compared to particleboard lie in their highly decorative properties, their ecological safety, and their durability and strength. Solid wood is widely used in the production of house furniture in highly-developed countries, and particleboard is displaced to the sphere of administrative and other furniture. It is common to use solid wood for facings, and particleboard for other parts of a piece of furniture.

Glulam panels and laminated boards are the main assembly units of furniture’s wooden components, which are produced by gluing solid boards arranged to fit each other according to quality, texture and colour. Optimally, these products are made from the wood of the same species.

In reality, producers often have to vary the types of wood they use in the manufacture of glulam panels and laminated boards, due to the impossibility of keeping all the various types of wood needed in stock at all times. The heterogeneous structure of different species and their distinctive behaviour under conditions of variable humidity necessitates an investigation.

Some problems do exist in home furniture manufacture: there is a need for production cost reduction and simultaneous quality improvement. These issues must be resolved in order to increase the competitive capacity of these goods.

Currently, raw material costs constitute 50 – 80% of overall production costs in Russian furniture plants, without exception. Thus there is an urgent need to search for cheaper materials, without compromising on quality.

The cheaper, higher quality and ecologically cleaner furniture from solid wood has already entered the Arkhangelsk market. The Arkhangelsk Plywood Factory specializes in making furniture from particleboard and plywood, while its competitors have begun manufacturing furniture from solid wood.

The main purpose of this graduation project is to propose the development of output furniture production from solid wood as the cheaper and ecologically clean material.

The Arkhangelsk Plywood Factory has a diverse raw material base that provides the necessary prerequisites for the development of solid wood furniture manufacture. Due to potential competition it is necessary to occupy marketing outlets in a timely manner and quickly implement new production methods.

However, there is a whole range of problems at the Arkhangelsk Plywood Factory which need to be solved first, in order to become competitive.

First of all, there is the state of capital assets. The accumulated depreciation in the machining workshop that could be used for solid wood furniture manufacture is 80-90%. Thus the shop requires extensive overhaul.

Secondly, low productivity is a major issue. Productivity could be improved by organizing straight line production and reducing the transport of partially-finished products through the shop.

Thirdly, the organizational structure of the manufacturing process is at present very inefficient. Nowadays, as is known, it is not economically advantageous to work in the sphere of technological specialization without taking advantage of available extra production capacity to manufacture additional items.

Mission and Vision

This project considers starting solid timber furniture manufacture. For this purpose it is selected an item of interest to be manufactured. A set of bedroom furniture will be designed.

Furniture should satisfy as much as possible potential consumers of the item. Thus market research will give the answer on the question what market capacity of the potential consumers of the set of bedroom furniture and which other items of furniture consumers want to buy.

A shop where furniture will be manufactured must be reconstructed. The reconstruction of the machining workshop considers to output solid timber furniture of interest and liquidation of shortcomings of the current engineering process.

Economical calculations show the viability of the reconstruction. To determine the viability of the production it is necessary to calculate all the costs needed for this production or to establish shop cost of the set of bedroom furniture. One special task of the project is to increase employee salary by a factor of 1.5.

The design of the furniture of interest should be depicted in the following working drawings (demi-A1 size): an overall view of the item, and a detailed drawing of the item in two drawings. For reconstruction activities the plan of equipment arrangement before reconstruction is needed to produce an equipment arrangement plan after reconstruction.

The possibility of combining two species of wood, pine and spruce in making glulam and how the surrounding environment and decorative and protective coatings affect combined glulam will be considered as well. If the quality of the glulam is corresponding standards the combined glulam has an important impact at the reducing workshop area and the cost decreasing.

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1 Theory

Some basic theories have been used in the diploma work:

- Marketing
- Production and Design
- Wood Material and Research
- Economy

1.1 Marketing

Marketing is a complex system of enterprise activity management whereby a commodity is developed, manufactured and sold, or where services are provided based on market study and influence on consumer demand. Marketing includes a number of activities: market research, product development, distribution, price-setting, advertising and sales. Market research and product development will be mostly considered in the thesis.

Marketing research serves a single purpose – that of providing information to assist marketing managers to make better decisions. The following types of research can be faced:

- **Concept tests**, using phone surveys and focus groups, explore the reaction of the potential audience to the idea behind a proposed series.
- **Pilot tests** measure the reaction of the potential audience to a filmed episode of the proposed series.
- **Series research** is conducted after a series is launched. Viewers are interviewed by phone to determine those aspects of the program they like and dislike /35/.

Marketing decisions involve three steps: (1) problem/opportunity identification, (2) problem/opportunity selection, (3) problem/opportunity resolution. Marketing research can provide useful information at each step.

Marketing research design – the specification of procedures for collecting and analyzing data to help identify or react to a problem opportunity. It is useful to consider three general categories of research based on the type of information required. These three categories are exploratory, descriptive, and causal.

Exploratory research is concerned with discovering the general nature of the problem and the variables that relate to it. Exploratory research is characterized by a high degree of flexibility, and it tends to rely on secondary data, convenience or judgment samples, small-scale surveys or simple experiments, and subjective evaluation of the results.

Descriptive research is focused on the accurate description of the variables in the problem model. Consumer profile studies, market-potential studies, product-usage studies, attitude surveys, sales analyses, media research, and price surveys are examples of descriptive research. Any source of information can be used in a descriptive study, although most studies of this nature rely heavily on secondary data sources and survey research.

Causal research attempts to specify the nature of the functional relationship between two or more variables in the problem model.

The thesis considers the first type – exploratory research.

1.1.1 Steps in the Research Design Process

1. Definition of the research problem.

Specify the information required to help react to the management problem.

2. Estimating of the value of the information to be provided by the research.

Use either judgement or the expected value approach.

3. Selecting of the data collection method(s).

Determine whether secondary data, a survey, or experimentation will produce the required data and choose the form of the selected method(s) to use.

4. Selecting of the measurement technique.

Determine whether and how to use questionnaires, attitude scales, observation, and/or projective techniques.

5. Selecting of the sample.

Determine who and how many respondents or objects to measure.

6. Selecting of the analytical approach.
7. Evaluating of the ethics of the research.
8. Specifying of the time and final cost.
9. Preparing of the research proposal.

Summarize the results of the preceding seven steps in the form of a research proposal.

Marketing research suggests that it is at first necessary to identify the need for a product, and then to determine for whom this product will be produced or its main clients. The need for a product or service is made by means of an individual needs classification matrix /23/.

The same commodity may be necessary for people to varying degrees but may not be equally accessible for purchase by different socio-economic groups. These groups might be determined by means of market segmentation. The principles of segmentation consist of the necessity of picking out the main characteristics of the buyers, which will exert an enormous influence on the selection of the specific type of product. A true marketing orientation requires that companies focus on meeting the needs of individual customers. In a simple world where consumers all have broadly similar needs and expectations, a company could probably justify developing a marketing programme which meets the needs of the 'average' customer. Customers are becoming increasingly diverse in their needs and aspirations, and less inclined to accept an 'average' product. Some of the bases for identifying different types of customers are familiar and readily observable, such as age, gender, and geographical location. Others, such as attitudes and lifestyle may be more difficult to identify, but can be crucial for understanding consumers' buying processes. The purpose of segmentation is to identify groups of buyers who respond in a similar way to any given marketing stimuli.

Understanding of different segments' needs influences the development of new products and adaptations of existing products.

Survey will be used to select the data collection method.

1.1.2 Surveys

Commercial surveys are conducted by research organizations and fall into three categories: periodic, panel, and shared.

Periodic surveys are conducted at regular intervals using a new sample of respondents for each survey.

Panel surveys are a group of respondents who have agreed to be interviewed over time.

Shared surveys are administered by a research firm and consist of questions supplied by multiple clients.

Survey research is the systematic gathering of information from respondents in an interview using a set of questions, generally in the form of a questionnaire. An interview is the administration of a questionnaire to an individual or group of individuals. Surveys are generally classified according to the method of communication used in interviews: personal, telephone, mail, or computer.

The selection of a survey method involves consideration of seven criteria: (1) complexity of the required questions, (2) amount of data required, (3) required accuracy, (4) sample control needed, (5) time available, (6) acceptable level of nonresponse, and (7) value of the resultant information and funds available.

We will use personal interview. In a personal interview, the interviewer asks the questions of the respondent in a face-to-face situation. The interview may take place at the respondent's home or at a central location, such as a shopping mall or research office.

Mall intercept interviews involve stopping shoppers in a shopping mall at random, qualifying them if necessary, inviting them into the research firm's interviewing facilities that are located at the mall, and conducting the interview. Qualifying a respondent means ensuring that the respondent meets the sampling criteria. This could involve a quota sample when interviews are desired of a given number of people with certain demographic characteristics such as age and gender. Or it could involve ensuring that all the respondents use the product category being investigated.

As mentioned earlier the tools of surveys are questionnaires. A questionnaire is a formalised set of questions for eliciting information. Constructing a sound questionnaire involves seven decision areas: (1) preliminary considerations, (2) question content, (3) question wording, (4) response format, (5) question sequence, (6) physical characteristics of the questionnaire, and (7) pretest.

The information required is developed from the project problem. The problem statement should provide a list of the required information. For each piece of information required, the questionnaire should contain at least one question. After a questionnaire is designed, answers to the questions should be created and analyzed. The answers should provide sufficient information to deal with the decision at hand. Any questions that provide data not needed to assist in the decision at hand should be dropped.

The key tasks in question phrasing are (1) to ensure that all respondents and researcher assign the same meanings to the terms used and (2) to avoid leading or biasing responses.

Open-ended questions provide the respondents with freedom to answer as they choose and can provide the researcher unexpected insights. However, they are harder for respondents to answer and require considerable effort to analyze. Thus these questions will not be used in the research. Multiple-choice and dichotomous questions are easier for the respondent to answer, allow less interviewer bias, and are easier to analyze. However, the alternatives must be developed with care.

Question should flow from the general to the specific. Personal or sensitive questions should be placed at the end of the questionnaire /35/.

1.1.3 Product Development

Marketing management includes the analysis, planning, promotion and control over activities, in order to determine and then support beneficial exchanges with buyers and achieve goals. Marketing management can be accomplished using five different concepts:

- The concept of product development asserts that consumers will buy products that are accessible through low prices, and therefore the task of management is to keep production costs low so as to be able to sell a product at lower prices.
- The concept of product development implies that consumers have a preference for high-quality products, and therefore extensive efforts to stimulate sales are not always required.
- The concept of commercial strength intensification asserts that products will not be purchased if consumers are not instigated by enormous efforts in the sphere of sales and stimulation.
- The concept of marketing is based on the assertion that a firm should determine through the use of surveys the needs and demands of a concrete market, and thus meet its requirements.
- The concept of socio-ethical marketing focuses on goal achievement, with its ability to provide consumer satisfaction and win the long term loyalty of the consumer and a society as a whole /36/.

The degree of newness of products is worth considering. New products could comprise any of the following:

- improvements/ revisions to existing products;
- additions to existing lines;
- new to the world products;
- new products lines;
- repositioning (existing products in new segments/markets);
- cost reductions

We will consider below innovative products. Innovative products are truly new products, comparatively rare compared to product modifications, but can be very important under certain circumstances:

- If consumers' tastes are changing radically, existing products may no longer satisfy their needs
- Technological change may make present products obsolete

- New products may be required as a result of changes in internal processes such as accounting, office management, or labour relations. If a product becomes dangerous or illegal to produce, a motivation is provided by a new replacement product to be developed.
- New products may be required to meet the need of intermediaries.
- The environment may have changed, creating new needs in the market.
- If competitors are actively developing new products, a company must be likewise if it is not to lose market share.
- New products may be developed to fill under-utilized capacity

Having a formal new product development process in place is still more likely to be effective than a haphard approach. It is usual to talk about a new product development process comprising a number of stages /36/:

1. Idea generation
2. Idea screening
3. Concept developing and testing
4. Business analysis
5. Product development and testing
6. Test marketing
7. Product launch

Every firm has to determine its own sales policy for selling its products. According to /23/, the first step of sales policy is that a firm makes a market characterization and defines its main competitors.

In a competitive marketing environment, a company must use all elements of the marketing mix /36/ to make its products the preferred choice of buyers. It is important seeing marketing management as a process of analysis, planning, implementation, and control. Any plan to develop a competitive advantage must be based on a sound analysis of just who a company’s competitors are. It is possible to identify direct and indirect competitors. A sound analysis of the direct and indirect competitors for a firm is crucial in defining the business mission of an organization.

A useful framework for analyzing the competition facing a company has been provided by Michael Porter /36/. His model illustrates the relationship between existing competitors and potential competitors in a market and identifies five forces requiring evaluation:

- the threat of new entrants;
- the threat of substitute products;

- the intensity of rivalry between competing firms;
- the power of suppliers;
- the power of buyers.

Understanding the structure of competition within a market is a crucial prerequisite for developing a strategy to develop a sustainable competitive advantage /36/.

1.2 Production and design

Furniture production is a complicated process. It involves design of furniture items, development of the process, reconstruction activities if they are relevant. A designer should use following principles to create a new furniture item. These principles are not enough without considering properties of the material, ergonomic demands. The new production supposes to make furniture from solid timber as the material.

1.2.1 General principles of solid wood furniture design

1. Development of technical tasks: a designer must formulate their demands for design of the item.
2. Development of technical propositions: the designer must select materials, and clarify the functional, esthetic, constructional and other aspects of the item.
3. Development of draft: variants of general overview and documentation are implemented. This enables the making of an experimental specimen /37/.
4. Development of working design documentation, i.e., the completing of working drawings of the item and its separate parts, with required specifications /5/.

1.2.2 General requirements for solid wood furniture design

1. Construction of the item, its shape, dimensions, amount and volume of depositories for storage, and their mutual disposition in the item must be applied according to functional designation and ergonomic demands, and style preferences as well.
2. Furniture design must provide the technology of its manufacture, simplicity of assembly and comfort of exploitation when material consumption is minimal.

3. Parts and assembly units must be unified and interchangeable, and at best, permit delivery of the item without preliminary assembly.
4. On the basis of part uniformity, many variants and different arrangements of a component should make it possible to prepare a variety of furniture sets.
5. Construction, facing and finishing materials must be selected according to the greatest correspondence between their properties and the working and esthetic demands of the item. It is also of importance during material selection to take into account economic demands – minimal material consumption, optimal technical terms providing the largest yield, and minimal labour consumption.
6. It is necessary to provide variants of facing materials, colour range, finishing, and decorations. This gives the additional possibility of increasing variety in equal production terms.
7. The item must be well-constructed, making it reliable and durable according to standard requirements /4/.

1.2.3 Technical rules for solid wood furniture design

1. The sections of panel and bar parts, which have a considerable external load, must be designed so that their deformations during exploitation will not exceed acceptable magnitudes.
2. The fibre structure of the wood must be taken into account. The direction of external loading must coincide with the fibre direction of the wood, and bending stresses must be perpendicular. Curved linear parts with a small radius of curvature must be made from bent, ply-curve or curve-cut semi-manufactured articles.
3. The optimal design of a part is when those areas under high loads have a larger section, strength or stiffness, and under low loads – vice verse.
4. Item parts must be constructed so as to minimize unavoidable dimension changes due to moisture content changes. Warping of gluelam depends on part dimensions and fibre arrangement. Warping is common when the width of the lamella does not exceed its thickness by a factor of 1,5 /19/.
5. Furniture design must be set up so as to minimize potential deviations of part dimensions and shape and also inaccuracy in assembly operations.
6. Separate parts must be connected rationally, taking into account the optimal quantity of eccentricities, establishing tolerance of dimensions and shape of parts, surface roughness, etc correctly /19/.

1.2.4 Material consumption

Material consumption is of vital importance for material planning and cost calculations. If we know dimensions of a part and stages of its manufacturing process then it is possible to calculate how much input materials we need. Processing tolerances allows us to calculate the original lumber using in the production. The volume of input materials will be calculated in the project using a guide /23/. Energy consumption is calculated by using guide /31 & 18/. Calculation of tools required is considered in /26/.

1.2.5 Lumber cutting

This is the first stage of wood processing. A constructor of any production line in furniture production should consider all advantages and disadvantages of different cutting schemes to improve the process.

The purpose of cutting is to obtain partially-finished parts from which the parts of required dimensions are obtained. During cutting of lumber some schemes of cutting are modified depending on the type of lumber, wood species and dimensions of the partially-finished parts /4/.

1. Cross-longitudinal cutting: crosscutting and cutting off defects, such as knots, rot, pitch, pockets etc, followed by longitudinal cutting to obtain the desired width.
2. Longitudinal-cross cutting: longitudinal cutting of the lumber, followed by crosscutting to obtain the desired length.
3. Crosscutting and cutting off defective spots, followed by marking-off components and following cutting.
4. Marking-off components and following cutting by Scheme 1 or 2.
5. Milling of one or two sides of the piece of lumber, then marking-off components and following cutting by Scheme 1 or 2.
6. Milling of a side, crosscutting and cutting off defects, listing of wane-edge boards, forming a base surface and gluing glulam panels, then marking-off and following cutting of curved components.

If edged lumber is used to obtain partially-finished parts of large lengths the following scheme could be useful:

7. Milling of a side of the piece of lumber, crosscutting and cutting off defects, finger-jointing by length, dimension moulding and crosscutting to obtain components.
8. Crosscutting of the boards, finger-jointing by length, crosscutting to obtain components, milling of sides and edges, gluing glulam panels, cutting of the panel to obtain components, dimension moulding.
9. Longitudinal cutting of the boards, crosscutting and cutting off defects, gluing lamellae into continuous beam, cutting of the beam into components.

The first six schemes are widely used in the production of furniture and building materials.

Scheme 2 is more effective in comparison with Scheme 1. The yield increases by 3%. This scheme is particularly effective when lumber of low quality is used. Scheme 4 is also more effective compared to Scheme 1, with the yield increasing by 9%. This scheme provides an opportunity to show internal defects after the milling process. If the length of the lumber is significant, then to save working area and labour Scheme 1 is used /4/.

It is customary to draw up cutting-to-length charts for plate and panel materials, to carry out the optimal dividing of large panels. It provides maximum yield and complete cutting by confirming the dimensions and the quantity of the input materials, and provides the opportunity to use specialized equipment.

1.2.6 Transport means in solid wood furniture production

Reconstruction of the shop involves analysis of what type of equipment is necessary to install to increase speed and effectiveness of the production line. Equipment in the furniture production can be divided in 2 types. The first type of equipment is that type which is necessary for transportation of raw materials and parts inside of the shop and outdoor in other shops. The second type is needed to produce these parts from raw materials.

Firstly equipment for transportation is considered. In the furniture plant an electric car with lift platform and electric loader are utilized. In cutting and machining, and occasionally in assembly workshops, hand trolleys are used. However, roller conveyors are widely used in furniture production nowadays. Because the use of floor non-drive rollers with supports and trays requires 1,6-1,8 times less working area to place the same amount of semi-manufactured parts stored on supports and trays, but in the last case a thoroughfare for an electric loader is necessary /23/.

The use of floor non-drive rollers enables a decrease in the performance rate required for transportation by approximately 25-30% comparing to electric loader /23/.

The floor rollers are installed horizontally to the flatness of the floor or at an angle of 2-9^0 in the direction of transportation of the parts. Sections of roller conveyor are made of three lengths and two widths: 1,5; 2; 2,5; 3 m and 800; 850 mm respectively. The floor non-drive rollers are easy to install and maintain. A stack of the parts is transported on the conveyor by pushing. A roller conveyor of length 2 m and width 800 mm is widely used in furniture plants.

The rollers revolve by means of roller bearings so that excessive effort is not required for transportation. At the end of the roller conveyor a locking device prevents the trays from rolling down during transportation.

Non-drive roller conveyors serve for transportation needs and stock of some parts.

The parts are transferred from one to another roller conveyor by a roller truck. The roller truck moves on rails. The roller trucks can be made with and without a pivoting floor /23/.

1.2.7 Equipment in solid wood furniture production

Engineering process of mechanical wood working must provide required accuracy – fidelity of a form, dimension accuracy and required surface roughness. These conditions must be taken in an account during definition of structure and sequence of technological operations, selection of equipment and destination of treatment condition. Mechanical timber processing must be built on the base of flow production, the scientific labour organization, a wide use of automatic and semiautomatic lines /18/.

Working out of engineering process, equipment selection for mechanical timber processing depends on production scale and production program. If volume of production is average it is advisably to use multi-purpose machines /18/.

Engineering process of mechanical bar working starts from smoothing and edging. To implement these operations one-sided facers with manual feeding of easy, average and heavy types, one-sided and two-sided facers with automatic feeding are most reliable.

Dimension moulding by thickness and width can be carried out at one-sided planers and four-sided moulders. For trimming disk saw with sliding table or jointer can be recommended /18/. If the production volume is high it is recommended to apply automatic lines to process parts.

For milling one-spindle multi-purpose moulding machines are widely used. For milling of outward contour roundabout millers are used. For milling of internal closed contours, grooves and slots profilers are used /21/.

Formation of frame tenon and eye are recommended to make by one-sided and two-sided tenoning machines or semiautomatic lines, to form dovetails dovetail jointers are applied.

To drill groves and drills drilling-grooving vertical and horizontal machines with mechanical feeding can be recommended. Working out of round and figured parts are produced at turning machines. The last operation of mechanical bar working of bars is sanding. It can be made at sanders with fixed table. If parts have plane concave and convex surfaces then they are sanded at drum sander machines.

Nowadays form working of panels are made at disk saws, millers and specialized lines. For addition and drilling of drills and grooves panel boring vertical and horizontal machines are applied. To sand faces of panels narrow bands sanders with sliding table and wide bands sanders or lines are used. To sand panel's edges edge or multi-purpose sanders with mechanical feeding are used /18/.

Depending on which lumber cutting scheme is applied during production, required equipment is selected from different catalogues /8/. Equipment can be different if to compare prices, producers, quality of received products, capacities, working place needed for production, amount of possible operations, convenience and simplicity during exploitation of the machine, possibility to install additional devices. Thanks to these factors equipment is selected.

1.2.8 Basics of enterprise design

The reconstruction process requires implementing such rules described below. Without them the arrangement of equipment and working areas in a shop can not ensure safety, comfort and high productivity, and as such it is made in accordance with the Scientific Labour Organization (SLO) /18/.

A shop plan is made in the following steps:

- draw the shop building (scale 1:50, 1:100, 1:200) and its main building components (walls, windows, doors, pillars and others).
- indicate the main thoroughfare and places where domestic and auxiliary rooms are placed.
- equipment and working areas are arranged together to obtain a straight-line engineering process and optimal organization of working areas.

- storages, equipment, thoroughfares, must be arranged so as to provide convenience and safety of work and maintenance, the ability to install, dismantle and repair equipment, convenience of supply and removal of parts and semi-manufactured items, waste cleaning.
- The thoroughfare must be 2 m of width if one-way traffic is applied and 3,6 m if two-way traffic. There must be transverse thoroughfares through every 50 m of shop length.
- if equipment exhausts pollutant emissions, it must be located in an isolated room.
- machines and lines must be arranged at a distance of 0,6-1 m from walls and pillars.
- the distance between two adjacent machines arranged sequentially (transit processing) must be not less than three times the length of the largest processing parts.
- the distance between two adjacent machines must not be less than 0,8-1 m.
- the organization of working area must have an arrangement of processed and processing stacks in relation to a worker /18/.

1.2.9 Adhesives applied in solid wood furniture production

Joining by means of adhesive is the main kind of jointing in a joiner's work. All kinds of joiner's bindings, the formation of large parts, and glue constructions in joiner's products ride on the strength of glue joints.

Urea and phenol glues are the most prevalent glues used with wood. In the production of items where wood is glued to other materials such as polyester, polyurethane and epoxy glues are applied.

PVA glue has found a wide use in furniture manufacture. This glue has a number of advantages compared to urea glue based on thermoplastic resins, which contain solvents /9/.

The advantages of PVA glue include:

- incombustibility;
- it is accommodating to deviations in gluing;
- the glue line is colourless and elastic that releases processing of glued parts and decreases tool deterioration;
- does not require a hardener and so has unlimited viability;

- fast hardening at both room and high temperatures;
- less toxic than urea-formaldehyde glues;
- resistant to aging;
- greater durability compared to urea-formaldehyde resins.

Disadvantages of PVA glue are:

- low heat stability (up to 40-60^{0}C);
- fluctuation under pressure;
- low water resistance.

Despite these disadvantages, PVA glue is during the present time the most acceptable, ecologically clean glue of the numerous joiners' products used for interior work. Two types of PVA glue, flexible and inflexible, are produced in our country according to AUSS 1892-80. During winter PVA glue is transported in two components – resin and softener, which are mixed before using /9/.

1.3 Wood material and research

1.3.1 Analytical review of literature and discussion of a problem concerning combination gluelam panel

Wood as an ecological and renewable raw material was and still is the material of choice for furniture and building. Modern furniture should not only be comfortable, but esthetically pleasing as well. At times furniture design proposes using different materials including different species of wood.

Concerning its application for the manufacture of glulam panels, some of its natural properties pose definite problems. Variable air moisture causes a change in the glulam panel geometry and dimensions as a result of shrinkage and swelling. The non-uniform distribution of physical properties in the volume of the panel (the wood's anisotropic properties) intensifies these negative phenomena and as a result glulam panels tend to warp. The relative humidity of the air inside a typical apartment in summer is 40-50 % and during winter in heated rooms is 25-

30 %. This means that the moisture content of the furniture ranges from 10 % to 6 % in summer and winter respectively /22/.

The most effective method of protecting wood products from a drop in moisture is through ”chemical stabilization” of the wood, i.e. impregnation by different chemical agents such as methacrylate methyl, phenol-formaldehyde or polyethylene glycol /10/. However, this method is labour- and time-intensive and as a result has not been widely adopted.

A constructional solution for the problem exists, with the practice of high quality woodworking. Much woodwork is more than one hundred years old but has had no depreciation in quality. The reason is that the construction enables the furniture to adjust to the dimension changes caused by the surrounding environment /21/.

It is worth noting the advantages of using glulam panels as opposed to solid timber in furniture production:

- Firstly, making glulam panels by gluing lamella ends is more profitable. Modern methods of individual timber dressing at band saws make it possible to use short logs (1,2-1,5 m). This is especially important when sawing valuable hardwood and leads to lumber yield increasing dramatically.
- Secondly, it is much easier to dry thin lamella in an efficient manner, i.e. to achieve the equal distribution of moisture content inside lamella, than for thick solid wood planks.
- Thirdly, the possibility of sorting single lamella based not only on appearance but also on quality enables the receipt of glulam panels of uniform quality /10/.

1.3.2 Definition of glulam panel categories

Glulam panels are blanks for furniture making. Technical terms TT GP 13-0273675-220-93 for glulam panels of general-duty as elaborated by the Central Research Institute of Mechanical Wood Processing (CRIMWP) make for two types of glulam panels – from blanks (type I), and from blanks previously glued along their length by finger joint (type II). There are two types of panels used for furniture parts. The first is termed decorative (D) and is used for panel framed doors and interior finish. The second is case wood (CW), for making shelves in subsidiary rooms, boxes, casing, and different constructions in individual houses /9/.

1.3.3 Properties of common pine and spruce

Pinus sylvestris makes up approximately 15 % of all the forest in Russia. Pine is the most widespread species /31/.

The timber of pine is characterized by excellent physical and mechanical properties, (in particular, the timber of the pines of northern European Russia). Due to its excellent physical properties, abundance and accessibility, pine is the most attractive tree for use among the coniferous species.

The heartwood of pine is characterized by the presence of resin canals, concentrated in latewood. Sapwood is a yellowish-white colour; heartwood is a pinkish or brownish-red colour. Growth layers are visible on all cut sets, with an abrupt transition from earlywood to latewood. Ray cells are not visible to the human eye. Timber has only verticillate knots. Height of the trunk is up to 52 m. Taper is 0,8 %.

Timber of pine is used in industrial and domestic construction, railway and agricultural construction, and is also widely used in bridge, carriage, automobile and transport construction, agricultural machinery and timber-aircraft construction, joinery and furniture production, construction components production, packing and so on /1/.

The timber of *Picea abies* is of a homogenous white color, sometimes with a slight yellowish or pinkish tint. Growth layers are visible on all cutsets. Latewood differs from earlywood by its darker colour. Ray cells are invisible. The timber is characterized by invisible difference in colour between heart wood and sap wood, and the presence of resin canals (these are few in number). In contrast to timber of pine, bigger knots are placed between nodes, among which little knots are present. Due to the abundance of knots, the timber of spruce processes poorly. Its advantages are a homogeneous structure, long fibers, and minor gumminess.

The timber of spruce is used in the same industrial spheres as pine, and especially in the pulp and paper industry and in making musical instruments.

The physical-mechanical properties of pine and spruce are shown in Table A.5.1 (Appendix A) /1/.

1.3.4 Terms and definitions used in the investigation

- **Definitions related to moisture theory**

The change in shape of glulam panel during drying, sawing and storage is termed *warping*.

Moisture content is used to describe the water content in timber. The state of the surrounding air is characterized by temperature t and relative humidity φ, which can range from 0 to 100 %.

Relative humidity is defined as the ratio of the partial vapour pressure in the air to the saturated vapour pressure, expressed as a percentage.

Timber is hygroscopic, that is it will absorb moisture from the atmosphere if it is dry and correspondingly yield moisture to the atmosphere when wet, thereby attaining a moisture content which is in equilibrium with the water vapour pressure of the surrounding atmosphere. Thus, for any combination of relative humidity and temperature of the atmosphere there is a corresponding moisture content of timber such that there will be no inward or outward diffusion of water vapour. This moisture content is referred to as the *equilibrium moisture content* or EMC. /1/.

The dehumidification of heartwood and sapwood are roughly equivalent. Increasing the bound moisture content in timber with a rising relative humidity in the surrounding air causes an increase in timber dimensions. This is called *swelling*. Conversely, the reduction in timber dimensions when the bound water evaporates into the atmospheres is known as *shrinkage*. Shrinkage and swelling are observed under 30 % of EMC.

Slight variations in the equilibrium moisture content will occur between species due to differences between them. There is a hysteresis loop between adsorption (the moisture content is increasing) and desorption (the moisture content is decreasing) /1/.

- **Test and experiment definitions**

An *experiment* is a system of operations, influences and observations aimed at gathering information about an object during investigation. An experiment consists of one or more tests.

A *test* is a reproduction of investigated phenomenon under prescribed conditions with the opportunity to register its results.

There are two basic methods of research: *experimental* and *theoretical*. The experimental method of investigation was chosen for our purposes. The purpose of experimental investigation is to study influences of different effects upon the object investigated. These effects are called *factors*. The results of these effects are estimated by indices, which called *estimated figures*. In our investigation the experiment was active, because the investigator defined factors in each test /11/.

1.3.5 Factors affecting the object under investigation

There are generally numerous factors that have an influence on any under investigation.

Those factors which exert a significant influence on the deformation of glulam are listed below:

- Moisture content
- Shrinkage and swelling properties
- Species of timber
- Density
- The structure of glulam
- Dimensions of lamellas
- Availability of coating

Factors which are less significant are as follows:

- Place of lamella cutoff from the tree trunk
- Place of tree origin
- Age of the tree
- Adhesive

Moisture content: (MC) exerts enormous influence on glulam panel because altering the relative humidity of the surrounding environment causes moisture content changes inside panel. Wood parts can change their moisture content during their exploitation period from 8 to 4 % /4/. Under these conditions their dimensions will vary depending on the degree of swelling and shrinkage.

Shrinkage and swelling properties: The degree of shrinkage differs along the three principal axes and between different timbers. Longitudinal shrinkage is less than transverse shrinkage by a factor of 10. Radial shrinkage is usually twice less than that of tangential. Swelling of timber is the reverse of shrinkage and generally behaves in a similar manner.

Density: The value of shrinkage is in hyperbolic dependence on density of timber. Denser layers of latewood of the growth ring dry up more than earlywood.

Degree of dehumidification depends on density as well. Decreasing the density of the timber and the corresponding relative increase of cavity volume increases the degree of dehumidification. All these interrelated factors exert direct action on the deformation of glulam panels.

Glulam should be constructed so as inevitable dimensional changes due to MC changes would be minimal. One of the methods to lessen these changes is the process of fitting lamellas depending on arrangement of growth rings. One way of doing this is shown in Figure 5.1.

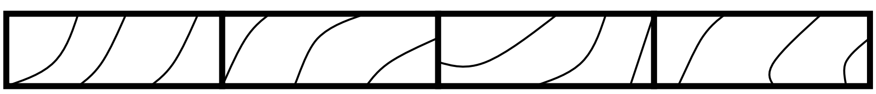


Figure 5.1 The profile of the glulam panel

Dimensions of lamellas: If furniture panels have dimensions greater than 100 mm they should be laminated from the blanks of less cross section. The upper allowance of cross section should be less than 100 mm, otherwise it leads to substantial deformation and poor panel quality.

Availability of coating: The ability to absorb water from the air is a negative property of the timber. By coating the surface of the workwood with paint or membranous materials it is possible to protect the wood from atmospheric moisture.

Place of lamellas cutoff from the tree trunk: Depending on what part of the tree trunk the lamella was cut off from, its properties will be altered as a consequence of the timber's anisotropic properties.

Place of tree origin: The site where the tree was grown affects the properties of the lamella. For instance, a tree from a swampy area will have a lower density than a tree from a dry location. However, it is impossible to take into account these factors because we have not followed the entire process of the given material for investigation. Thus, these factors are considered unimportant, and disregarded.

Adhesive: Adhesive likewise does not play a significant role in the investigation. This is because of the adhesive's high strength. This strength is sufficient to overcome deformations along glue joints emerging under a relative drop in humidity.

Moisture content, the presence of coating on the workwood surface, and the timber species and thereby its physical-mechanical properties will be related to variable factors. All other factors will be constant in the investigation.

1.3.6 Choice of assessment criterion for investigated process

Assessment criterion of the investigation is deformation of glulam. The deformation will be described by profile of the panel and determined by largest deviation (d) of the panel's surface from the plane. This is shown in Figure 5.2.

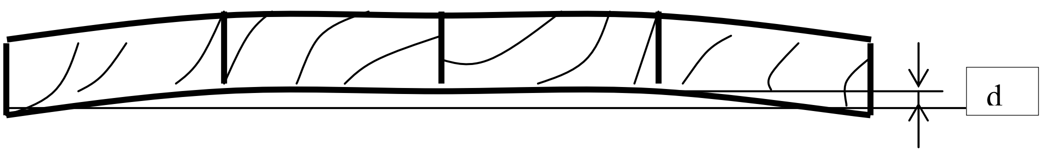


Figure 5.2 The profile of the glulam

1.4 Economy

In the market economy indicators of capital investment viability are used. These indicators are given below:

- Cash flow (CF_t) over a specified period:

$$CF_t = Q_t - K_t - U_t \,, \tag{1.1}$$

where Q_t – income over a period of time t;

K_t – capital investments over a period of time t;

U_t – all current costs over a period of time t.

- Cumulative Cash flow (*CCF*) is calculated as the sum of cash flow in a given period of time and cash flow in the prior period.
- Discounting Cash flow (*DCF*) is determined by the formula:

$$DCF = CF_t * \alpha_t = CF_t * (1+E)^{(tp-t)} \tag{1.2}$$

where α_t – coefficient of discounting by the factor of time (Table A.4.16);

E – rate of discounting is taken as the average interest from the Central Bank of Russia, E = 13 % in 2004 year;

t_p – calculated period of time to which reduction is made.

- Net Present Value (*NPV*):

$$NPV = \sum_{ti}^{tf} CF \cdot \alpha_t \tag{1.3}$$

where t_f, t_i – correspondingly initial and finite intervals;

t – some time in the interval.

If *NPV*=0, the investor provides only the replacement of capital at the expense of income.

- Maximum Cash Exposure (*MCE*) or maximum capital investment.
- Internal Rate of Return (*IRR*) is a maximum percentage that the investor can count on to cover the project for definite period of time. *IRR* is a normative value of *E* when *NPV*=0.

If $IRR > E$ the project is economically viable

If $IRR = E$ it is necessary to find a way so that $IRR > E$.

If $IRR < E$ the project is not economically viable.

- Payback (*PB*) is determined by the sequential summation of investments and incomes until that period of time when cumulative cash flow turns from minus to plus.

$$PB = T + \frac{(CF_t - 1)}{CF_t}\,, \tag{1.4}$$

where T – payback as a integer;

$(CF_t -1)$ – cash flow in the last month it is negative

CF_t – cash flow in the first month it is positive

Payback can be determined by using the finance profile of the project depicting cash flow.

- Profitability Index (*PI*) shows how much profit a company would earn from one ruble of investment:

$$PI = NPV/K_t \tag{1.5}$$

where K_t – total capital investments reduced by the factor of time.

2 Materials and methods

2.1 Consumers' Market Research

A simple design of a set of bedroom furniture in the light and natural colours of pine is proposed. The output program calculation of the set of bedroom furniture that is planned for manufacture at the Arkhangelsk Plywood Factory will be worked out using marketing investigations. These marketing investigations have been conducted in Arkhangelsk, Novodvinsk and Severodvinsk.

To sell any product it ought to be analyzed for its necessity. The set of furniture proposed in this project is intended for the interior of a bedroom. Every element of the set of bedroom furniture performs different functions. The main element is a double bed. The fundamental purpose set of this is to satisfy primary needs of man, such as sleep. Sleep is necessary for everybody.

Other furniture in a bedroom plays the role of a depository for clothes or other private articles. The common element of all the items of the bedroom furniture set is that although they may perform different functions, they are to be made in the same style and colour range.

Contemporary-styled sleeping furniture should be comfortable and cosy. It is interesting to note that each person perceives comfort and cosiness differently, with various preferences regarding colour and furniture design. Contemporary-styled furniture (Fig.2.2) has simpler design and decor is used less if to compare to the classical style (Fig. 2.1). Furniture design emerged in 18-19th centuries became classical nowadays. This furniture design was complicated with using many elements.

Many people in today's society feel that furniture should be safe from an ecological perspective. Man spends the majority of his life in the bedroom. Thus it is natural that furniture should not be harmful and that it should be ecological. The most ecological and natural material is solid wood.

Figure 2.1 Set of bedroom furniture in classical design

Figure 2.2 Set of bedroom furniture in contemporary design

2.1.1 Market segmentation

There are two client types in the market:

1. Private consumers – individuals purchasing furniture for private use.
2. Public consumers – hotels, etc. purchasing furniture for use in the service sphere.

The public consumers' market is not considered in this thesis.

Potential consumers can be determined by means of market segmentation. Three indications of segmentation are chosen:

1. Demographical indication

Population data regarding Arkhangelsk, Novodvinsk and Severodvinsk were taken from the Arkhangelsk Administration Statistics Department. There are approximately 440,000 people in Arkhangelsk including 122,000 families; 50,000 people in Novodvinsk including 16,000 families, and 235,000 people in Severodvinsk including 72,000 families. The population is divided into three groups: under 25 years of age, 25 to 55, and over 55. The first and the last groups as a rule are not expected to purchase a set of bedroom furniture.

2. Level of income

Every family has a different income level. Determining segment by level of income is necessary to ensure that the selected segment will provide a stable level of sales to the producer.

3. Preference of furniture styles

Different people prefer furniture in different styles; hence if the project suggests making furniture in a contemporary style, it is necessary to identify that segment of consumers who prefer the contemporary style to the classical.

2.1.2 Sales policy

a) Market characterization

Russian furniture production is currently developing at a rapid rate. However, furniture is predominantly made from particleboard and MDF. Italian, German, Taiwanese, Byelorussian and, of course, locally produced furniture can be found in Arkhangelsk furniture salons. If the displayed furniture is not to a shopper's taste, he can choose furniture from catalogues or magazines. Solid wood furniture is generally in the "classical" style, and furniture made from particleboard is generally in the "modern" style. At this point in time it is impossible to find the type of bedroom furniture that is proposed by this project in the Arkhangelsk region.

b) Market capacity

Bedroom furniture represents roughly 15% of all furniture in the salons of Arkhangelsk, Novodvinsk and Severodvinsk. About 30 % of the furniture assortment is foreign-produced. The sets of cushioned furniture and kitchen furniture are currently in great demand in the Arkhangelsk market. As regards bedroom furniture, beds are in demand. This tendency is a result of the high cost of complete bedroom suites. At present the market capacity is estimated to be sufficient for realization of the project.

Within the limits of this project, the primary consumers of bedroom furniture sets are families who prefer inexpensive solid wood furniture. This type of furniture is popular in Scandinavia, the USA and in other countries. The furniture discussed in this thesis could potentially be sold abroad; such furniture is suitable for hotels and country-cottages. However, these considerations represent a second step of the project, and are not dealt with in this thesis.

The most refined sets are of a classical style and come from Italy. These are primarily made up of valuable species of wood. 70% of producers are domestic. 20 % of these domestic suites are produced in Moscow and St. Petersburg, and are in great demand.

The sets of bedroom furniture manufactured in our region represent 40% of all sets of furniture sold in the salons of Arkhangelsk, Novodvinsk and Severodvinsk, or 6 % from all presented listed furniture. The market capacity of sets of bedroom furniture would be considered 6 % as well. This figure was derived approximately, with an allowance for increasing market capacity in the Arkhangelsk region. Market capacity is represented in Figure 2.3.

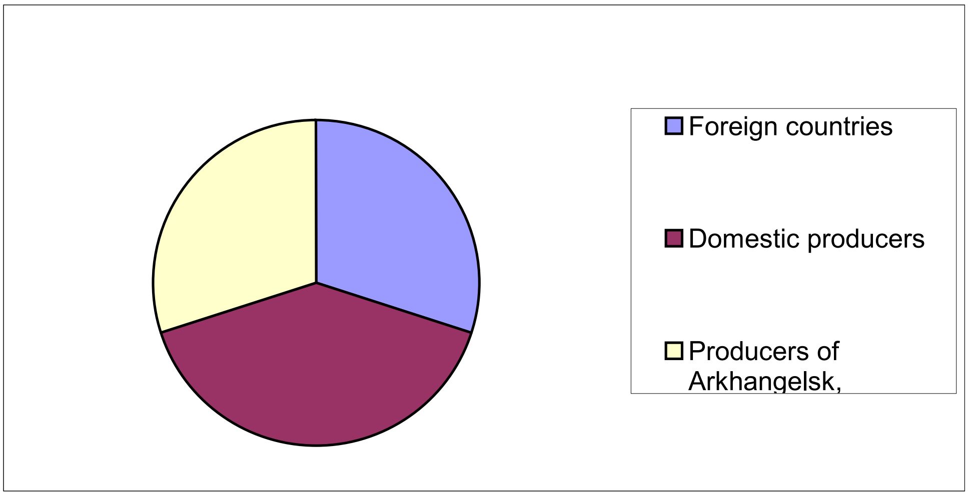


Figure 2.3 Market capacities of sets of bedroom furniture in Arkhangelsk, Novodvinsk and Severodvinsk

2.1.3 Consumers' market survey in Arkhangelsk, Novodvinsk and Severodvinsk

The fundamental task of the market survey is to establish the number of potential buyers of a set of bedroom furniture. It is also of vital importance to identify those properties of the set of bedroom furniture which will best meet the demands of the majority of consumers.

To implement the stated purposes a questionnaire was composed in Appendix B.

A total of one hundred copies of this questionnaire were printed and distributed, in which the most relevant issues concerning marketing were put forward.

2.1.4 Annual demand calculation

Annual demand for a set of bedroom furniture is calculated by the formula:

$$N_a = N_a^A + N_a^B, \tag{2.1}$$

where N_a^A, N_a^B – annual demand for a set of bedroom furniture in the segments A and B, pieces.

$$N_a^A = \frac{(N_{Ark} + N_{Nov} + N_{Sev})X^A}{K^A}; \; N_a^B = \frac{(N_{Ark} + N_{Nov} + N_{Sev})X^B}{K^B}, \tag{2.2}$$

where N_{Ark}, N_{Nov}, N_{Sev} – number of families in Arkhangelsk, Novodvinsk and Severodvinsk;

X^A, X^B – percentage of those surveyed in the segments in relation to the number of surveyed participants who wished to buy a set of bedroom furniture;

K^A, K^B – mean service term of furniture A and B segments, years.

The service term of furniture is calculated as the arithmetic mean of all the answers in the questionnaire.

The annual program for the output of the set of bedroom furniture can be obtained by the formula:

$$E = \frac{N_a \cdot n}{100}, \tag{2.3}$$

where n – market share, % ;

2.2 Technical calculations

2.2.1 Technical description of the set of bedroom furniture

A set of bedroom furniture has been designed as part of the thesis.

The set of furniture is rendered in a contemporary style and intended for the interior of a bedroom. In our case it is made from pine of I-IV grades /12/ but it may be made from any other species of softwood or hardwood. All of the items are designed as collapsible articles. Collapsible articles allows to assemble and disassemble different elements.

A double bed is related to furniture for seating and lying by its functional designation /13/. Functional sizes of the double bed correspond to standard /14/. The size of berth is 1800x2000 mm.

The double bed consists of a headboard and footboard, two bed frames, four legs, bars and a bed grill. The bed frames, backs and legs are joined using furniture hinges.

The headboard has a frame construction; the footboard is glued from pine lamellae in a glued-up panel. The glued-up panel should correspond to /24/.

The bed frames (length 2000 mm, thickness 30 mm) are made from lamellae and serve as a support for the bed grill. The bars (cross section 36 x 30 mm) are fixed to the bed frames by connecting screws (length 50 mm and diameter 5 mm /15/).

The bed grill under the mattress (size 2000x1800 mm) has a frame construction. The bars from plywood are set in the bed grill. Plywood should correspond to Grade III /16/. The bed grill is placed on the support bars.

The legs are glued from two planks (cross section 40x80 mm). The strength indices of the legs should comply with LTM 08.477-70.

The body of the bedside table, chest of drawers and folding wardrobe has construction elements made from the glued-up panels. The back wall of the bedside table, chest of drawers and folding wardrobe is made from fiberboard /17/.

The functional dimensions of the storage units (for clothing, linen or other items) should correspond to /18/.

The mirror is set in a rectangular frame (1100x1000 mm). The mattress and mirror are related to the purchased.

The protective-decorative coating of the furniture surfaces should correspond to standard /19/.

All dimensions of the parts of the bed are specified (Appendix A Table A.2.3).

2.2.2 Calculation of the production program

The company produces some parts in the reconstructed shop. To produce these parts and to add new items in the production is necessary to reduce all items to one. It makes also easier further calculations.

To work out the engineering process and calculate the required amount of equipment in the reconstructed workshop, the production program is reduced through converse factors to one representative item. The double bed is taken as this item. Calculation is made in Appendix A Table A.2.1.

It is also necessary to reduce all products currently produced in the machining workshop. The reduced program for the whole range of items is given in Appendix A Table A.2.2. The following calculations are carried out for the double bed.

2.2.3 Drawing of working drawings

The AutoCAD 2002 technical drawing computer program was used to draw up an overall view of a double bed program. A detailed drawing of the double bed has been drawn by using /25/ and /34/ to determine values of surface roughness, allowances and fits of the parts. Arkhangelsk Plywood Factory represented materials required to make up a general layout of the factory and a plan of equipment arrangement before reconstruction at the drying and machining workshop. Working drawings have been made according to Standard of enterprise /29/.

2.2.4 Calculation of primary and secondary material requirements

The aim of this calculation is to determine the required quantity of materials for constructing the double bed. Input data are the working drawings, specification (Appendix A Table A.2.3) and the engineering process.

2.2.4.1 Calculation of timber-based material requirements

The calculation is made in the following order: the volume of dimension parts is calculated, followed by the volume of dummies with machining allowances, the volume of dummies with process losses and the volume of input materials taking into consideration a volume yield after timber dressing. The calculation is performed separately for every part of the specified double bed (Appendix A Table A.2.4).

As mentioned earlier the primary material is pine wane-edge lumber 5 m in length.

The volume of the dimension parts V_p, m^3 is given by:

$$V_p = \frac{h_p l_p b_p}{10^9}, \tag{2.4}$$

where h_p – thickness of the dimension part, mm;

l_p – length of the dimension part, mm;

b_p – width of the dimension part, mm;

Volume of the parts in the item V_i, m^3 is given by:

$$V_i = V_p n_p, \tag{2.5}$$

where n_p – quantity of the parts in the item, pieces.

Volume of the parts required for the production program V_p^p, m^3 is calculated as:

$$V_p^p = V_i n, \tag{2.6}$$

where n – production program, pieces.

The values received are put into the corresponding columns 5, 6, 7 and 8 of Table A.2.4 (Appendix A).

The machining allowances are calculated depending on the designation of the part, its dimensions, and its material and technology features according to AUSS 7307-75.

Shrinkage allowance for all the parts is equal to zero because used lumber has a moisture content of 8%.

Volume of the dummies (V_d) is calculated similarly. Volume of the dummy in the item V_d^i, m^3 is given by:

$$V_d^i = \frac{V_d n_d}{K_l K_b K_h}, \tag{2.7}$$

where K_l – repetition factor of the parts in the dummy by length, pieces;

K_b – repetition factor of the parts in the dummy by width, pieces;

K_h – repetition factor of the parts in the dummy by thickness, pieces.

The volume of the dummies required for the production program V_d^p, m^3 is calculated as:

$$V_d^p = V_d^i n, \tag{2.8}$$

The process losses (l) are taken based on using raw materials /32/ from the volume of the dummies needed for the program. The process losses for wane-edge lumber are 3% and for plywood it is 2%.

The volume of the dummies with process losses V_d^{los}, m^3 is found by:

$$V_d^{los} = \frac{100 + l}{100} V_p^l, \tag{2.9}$$

Volume yield (K, %) from timber-based materials depending on the material used and its grade is taken from Table 3 /32/. Volume yield for wane-edge lumber is 62% and for plywood is 85%.

Timber consumption V, m^3 is calculated by:

$$V = \frac{V_d^{los}}{K} * 100, \tag{2.10}$$

By adding all the cells of columns 11, 24, 26, 28 (Appendix A Table A.2.4), total volumes of the parts, dummies and timber are arrived at. This calculation is presented in Table A.2.7 (Appendix A).

2.2.4.2 Calculation of panel material requirements

A suitable material for bars of the bed grill is a plywood panel. To optimize the cutting process of the bars it is necessary to draw cutting-to-length charts. Thickness of a sawing kerf must be taken into account. If the thickness of a saw is taken as 2.2 mm then thickness of the kerf is 3.8 mm according to /32/. The cutting-to-length chart is shown in Figure 2. Calculation of plywood quantity is in Table A.2.5 (Appendix A).

Volume yield of the bars V_s, % cut from the standard panel is given by:

$$V_s = \frac{S_p}{S}100, \tag{2.11}$$

where S_p – sum total of squares of the bars cut from the standard panel, m^2;

S – square of the standard panel, m^2.

2.2.4.3 Timber Specification

Based on calculations in Tables A.2.4 and A.2.5 (Appendix A), timber specification is presented in Table A.2.6 (Appendix A).

The technical title for the timber is listed in column 2 according to AUSS. The required amount of timber according to the above calculations (Tables A.2.4 and A.2.5) can be found in columns 9 and 10 of Table A.2.6 (Appendix A).

2.2.4.4 Calculation of adhesives requirements

Calculation of adhesive consumption is made in the following manner: the area of the glued surface is calculated (Table A.2.7 (Appendix A)), the adhesive type and gluing conditions are selected, and adhesive consumption is calculated by standard expense allowance according to the complexity group it belongs to.

The adhesive consumption calculation is presented in Table A.2.8 (Appendix A).

2.2.4.5 Calculation of component requirements

Component consumption is determined directly from the working drawings. The determined number of components is increased by the percentage of defective parts. Thus the furniture fittings and metals are increased by 5%, plastic things – by 1%, glass things – by 1% /20/.

Calculations are presented in Table A.2.9 (Appendix A).

2.2.5 Analysis of the engineering process at the machining workshop

The raw materials for the manufacture of solid wood furniture are softwood lumber /12/ and hardwood lumber /20/. Sawn lumber is sawn from sawlogs delivered in two lengths, 5 and 6,2 m. The sawlogs are splitted at a saw frame R-63 to obtain the lumber of the required section.

Wane-edge timber is sorted, stacked and transported to a buffer storehouse. The timber is then dried in drying kilns SPM-2K to a moisture content of 8 ± 2 %. After drying, the stack of timber is transported by stacker truck to the drying and machining workshop. Wane-edge timber is moved to a crosscut saw ZPA-40 where the slabs are cut to length and defective spots are cut off. Then along-the-grain sawing and edging is accomplished by ripsaws ZDK-4 and ZDK-5-2. There is a disk saw ZA-2A for the deep cutting of the slabs installed adjacent to a four-sided moulder S25-4-UHL4. The slabs are dimension sawn by Z6-2.

Base forming is made by facers SF4-1A or SF6-2. Thicknessing at thicknessing planers SR3-6 и SR6-10 is then carried out. Four-sided planing is made by the four-sided moulder S25-4-UHL4.

Gluer KV is used for gluing some pieces together, in conjunction with clamping devices to keep them under pressure.

Depending on their designation, pieces are subjected to various mechanical treatments. For instance, slabs for stool or table legs are subjected to turning at a turning machine or rod machine KPa50-1. Grooving is done by F-4. The milling machine with tenoning head FSSH-1A cuts the tenons.

Sanding operations can be accomplished at sanding machine SHlPS-5, drum sander machine SHlDB or edge sander SHlNSV. There are two non-standard sanders for fine-detail sanding in the machining workshop. Machines SVA-2 and SVPA-2 are installed for drilling-grooving operations.

The current engineering process in the shop has some shortcomings. These include:

- A large percentage of obsolete and worn-out equipment, resulting in inaccurate work.
- A low efficiency of installed equipment.
- A from-point-to-point positioning of equipment, which does not permit rational and efficient use of the working areas.
- Manual labour is widely used in handling operations.

2.2.6 Reconstruction activities in the machining workshop

On the basis of the conducted analysis of the existing engineering process in the machining shop and the need for an efficient production process for solid wood furniture, a number of reconstruction activities are proposed within this project:

- Dismantling old equipment and installing new equipment (Table A.2.11).
- Application of a floor-type conveyor system.

New equipment has been selected from a catalogue of woodworking equipment /8/ according to principles described in the Theory chapter. Knowing how much equipment reconstructed shop is needed and using working drawings mechanics conduct dismantling and installing processes in the shop.

2.2.7 Calculation of equipment required by standard time

The required time *T*, in machine-hours, for the physical operation to make the production program is given by:

$$T = \frac{N_t n_p n K_n}{100 K_x}, \tag{2.12}$$

where N_t – standard time to process 100 parts, machine-hours;

$$N_t = To\left(1 + \frac{K}{100}\right), \tag{2.13}$$

where *To* – cycle time for making 100 parts, machine-hours, is chosen from Tables of uniform collected measurement data /37,38,39/;

K – coefficient of regulated conversion costs in percentage to cycle time, %, is chosen from Tables of uniform collected measurement data /37,38,39/;

n_p – a number of the parts in the item, pieces;

n – the production program, pieces;

K_n – coefficient considering waste of some parts, K_n =1,02…1,07;

K_x – repetition factor of the parts in the dummy.

The total time required to accomplish processing at the given machine for all the parts of the item is found by:

$$Tn = \sum T \tag{2.14}$$

The calculated number of machines required for the production program N_m, machines, is determined by:

$$N_m = \frac{Tn}{T_{ef}}, \tag{2.15}$$

where T_{ef} – annual effective time schedule of machine's work, T_{ef}=1913 hours (Table A.5.5 (Appendix A))

Machine usage ratio:

$$P_u = \frac{N_c}{N_t}, \tag{2.16}$$

where N_t – taken number of machines, pieces.

The machine productivity calculation by standard time is presented in Tables A.2.12 and A.2.13 (Appendix A). The actual machine utilization is calculated by formulas 2.12-2.14. Results are presented in Table A.2.14 (Appendix A).

The productivity of some machines is calculated using other formulas.

The productivity of a gluer KV2-3, P, pieces/shift, is found by:

$$P = \frac{TUK_w K_m}{L}; \tag{2.17}$$

where T – shift duration, T= 480 minutes;

U – feed speed, U=6,1 m/min;

K_w – coefficient of working time usage, K_p=0,95;

K_m – coefficient of machine time usage, K_m= 0,5;

L – average length of the parts in the item, L=1,47 m.

Annual productivity of the gluer P_a, pieces/year, is given by:

$$P_a = PT_{ef}C, \tag{2.18}$$

where T_{ef} – annual effective time schedule of machine's work, T_{ef} =239 days;

C – shift number, C=1 shift.

Required number of parts for the program Q, pieces, is calculated thus:

$$Q = nN, \tag{2.19}$$

where n – the production program, pieces;

N – number of parts in the item subjected to gluing, N=30 pieces.

The required number of gluers is calculated by:

$$N_m = \frac{Q}{P_a}, \tag{2.20}$$

The productivity of the clamping device VR-6 is given by:

$$P = \frac{NTK_w}{t}, \tag{2.21}$$

where N – number of panels in one pressing in, N = 12 panels;

t – cycle time of one pressing in, min;

$$t = t_{gl} + t_{aux}, \tag{2.22}$$

where t_{gl} – gluing time, t_{gl} =30 min.,

t_{aux} – time for auxiliary operations, t_{aux} =7 min.

Annual productivity of the clamp device P_a, panels/year, is calculated by the formula (2.18). Required number of the gluelam panels for the program Q, panels, is calculated using the formula (2.19). The required number of clamping devices is calculated by the formula (2.20).

2.2.8 Calculation of tools required

The tool stock of the enterprise must support the primary production process with quality woodworking tools, as well as timely tool grinding, tool dressing, and speedy tool replacement during the operational process.

The calculation of tools required is as follows:

$$P = \frac{100TNB}{at(100-d)}, \tag{2.23}$$

where T – required number of machine-hours for the program, machine-hour, (Table 2.14 (Appendix A));

N – number of tools simultaneously installed at one machine, pieces;

B – average tool reduction for one refile including natural deterioration during cutting process, mm, (Table 22 /40/);

a – magnitude of allowable sewing-up, mm, (Table 22 /40/);

t – average duration of the tool working without refile or tool life, hour, (Table 22 /40/);

d – percentage of breakage and unforeseen tool consumption, (Table 22 /40/).

Results are presented in Table A.2.15 (Appendix A).

2.2.9 Calculation of required workshop working area

Furniture production at the factory requires buffers at the different stages of production line. Then the working area consists of the areas for equipment, the input and output storages, and the processing storages and auxiliary areas.

The working area Fn, m^2, is calculated by the formula (2.24):

$$Fn = \frac{Fp + Fc}{0,6}, \tag{2.24}$$

where Fp – area of workplaces, m^2;

Fc – area of the input and output storages, processing storages, m^2

0,6 – coefficient taking into account a thoroughfare for transport.

$$Fc=F_1+F_2+F_3, \tag{2.25}$$

where F_1, F_2, F_3 – area of the input, output and processing storages respectively, m^2

The area of the input storage F_1 is taken from the layout of the machining workshop before reconstruction, F_1= 210 m^2.

The area of the processing storage is determined by formula (2.26). In this case processing storage is a buffer for the gluing-up panels after the gluing process.

$$F_2 = \frac{QcN}{(B \cdot Bc \cdot h)}, \tag{2.26}$$

where Qc – amount of materials stored at one time in a storage, Qc = 0,597 m^3;

B – coefficient of piled stack's filling, B = 0,4-0,8;

Bc – coefficient of storage's filling, Bc = 0,5-0,6;

h – height of the stack, m.; h = 1,2 m.

N – storage period, N = 0,21 shift.

The area of the output storage F_3 is taken from the layout of the machining workshop before reconstruction as well, F_3=80 m^2.

Calculation of the workplace area required is presented in Table A.2.16 (Appendix A).

2.3 Power and water consumption calculations

The power requirements will change from the current consumption, due to new equipment application and the increasing of some machines' utilization. Total power consumption is found by the formula:

$$Q_t = Q_p + Q_l, \tag{3.1}$$

where Q_p – power electrical energy consumption (Table A.3.1 (Appendix A));

Q_l – electrical energy consumption for lighting (Table A.3.2 (Appendix A)).

2.3.1 Energy consumption

2.3.1.1 Energy consumption by equipment

This calculation considers machine utilization and energy losses during equipment use.

- The required capacity of the electric motors P_n, kW, is given by:

$$P_n = \frac{P_i h_1}{h_2 h_3}, \tag{3.2}$$

where P_i – installed capacity of electric motor, kW;

h_1 – usage of electric motor, h_1 = 0,6-0,7;

h_2 – efficiency of electric motor, h_2 = 0,75-0,9

h_3 – efficiency of mains, h_3 = 0,95.

- Annual energy consumption Q_a , kWh, is defined as follows:

$$Q_a = P_n Tn \tag{3.3}$$

where Tn – annual time schedule of machine's work, machine-hours.

The calculation of consumed energy by machines is presented in Table A.3.1 (Appendix A).

2.3.1.2 Energy consumption by lighting

Industrial, administrative, domestic and auxiliary buildings are illuminated by electric light. LD-80 luminous lamps are used for lighting.

- Calculated capacity:

$$P_c = pS, \tag{3.4}$$

where p – power density expended on lighting;

S – area of a room, m^2.

- Installed capacity:

$$P_i = P_c K_3, \tag{3.5}$$

where K_3 – safety factor considering a decline in lighting, K_3 = 1,3 /40/.

- Required capacity:

$$P_n = \frac{P_i B}{H}, \tag{3.6}$$

where B – capacity factor considering nonsimultaneous operation of all lamps, B = 0,85;

H – efficiency of mains, H = 0,95 /40/.

- Annual energy consumption:

$$Q_a = P_n n + 0{,}1 P_n n, \tag{3.7}$$

where n – number of burning hours, (Table 29 /40/), n = 650 hours.

The calculation of energy consumption for lighting is presented in Table A.3.2 (Appendix A).

2.3.2 Water consumption

- Annual consumption is given by:

$$Q_a = Q_{hn} + Q_w + Q_{fp} + Q_s \tag{3.8}$$

- Water consumption for household needs:

$$Q_{hn} = \frac{(25...45)nN_c}{1000}, \tag{3.9}$$

where (25...45) liter/hour – rate of water application by one person per shift;

n – number of workers, n = 30 workers;

N_c – number of shifts a year, N_c = 251 shifts.

- Water consumption by the wash-stands:

$$Q_w = \frac{200 \cdot 0{,}75nN_c}{1000}, \tag{3.10}$$

where 200 – rate of water application by one wash-stand, liter/hour;

0,75 – working time of the wash-stand, person/shift;

n – number of wash-stands, pieces;

- Water consumption for fire prevention needs:

$$Q_{fp} = \frac{ab(600N_{out} + 300N_{in})}{1000}, \tag{3.11}$$

where a – number of weeks a year, a = 52 weeks;

b – testing time of a hydrant, b = 5 minutes;

N_{out} – number of exterior hydrants (should be installed through every 100 m), N_{out} =3;

N_{in} – number of interior hydrants (through every 25 m), N_{in} = 5;

600; 300 – water consumption by interior and exterior hydrants, m/min;

- Water consumption by the showers is calculated by:

$$Q_s = \frac{nATN_c}{1000}, \tag{3.12}$$

where n – number of showers;

A – hourly consumption of water by one shower, A = 500 liters/hours;

T – working time of the shower, T = 0,75 hour/shift;

2.3.3 Heat consumption

2.3.3.1 Heat consumption for the buildings

To maintain a room’s required inside temperature it is necessary to reduce the relationship between heat gain and heat loss of the building.

- The heat balance of industrial rooms is calculated thus:

$$Q_h = \sum Q_l - \sum Q_i, \quad (3.13)$$

where Q_h – heat consumption;

$\sum Q_i$ – total internal calorification;

$$\sum Q_i = Q_{eq} + Q_{light}, \quad (3.14)$$

$\sum Q_l$ – total heat loss;

$$\sum Q_l = Q_e + Q_{in}, \quad (3.15)$$

where Q_e – heat loss by heat transfer through enclosures;

Q_{in} – heat loss by inleakage due to cold air coming in the building through leakages of the outside enclosures;

$$Q_e + Q_{in} = (1+\mu) y_0 V (t_i - t_e), \quad (3.16)$$

where μ – coefficient of inleakage, μ = 0,27...0,38;

y_0 – specific heat of the building, y_0 = 0,45;

V – volume of the building by outward measure, V = 16800 m^3;

t_i – calculated temperature of internal air in the heat building, $t_i = 18\ ^0$ C;

t_e – calculated temperature of external air, $t_e = -\ 33\ ^0$ C

The calculation of the quantity of heat generated is thus:

- Quantity of heat evolved by the equipment is calculated using the formula:

$$Q_{eq} = 10^3 \cdot \sum N_i \cdot K_u, \quad (3.17)$$

where $\sum N_i$ – total installed capacity of the electric motors, $\sum N_i$ = 125,7 kW (Table A.3.1 (Appendix A));

K_u – usage of installed capacity, machine utilization and simultaneous working of the machines, K_u = 0,5;

- Quantity of heat generated by the electric lights is found by:

$$Q_{light} = 10^3 \cdot \sum N_l \cdot P_l, \quad (3.18)$$

where $\sum N_l$ – total installed capacity of all candlelights, $\sum N_l$ = 40,56 kW;

P_l – coefficient taking into account the quantity of heat from lighting, P_l = 1;

- Heat consumption:

$$Q_h = (Q_e + Q_{in}) - (Q_{eq} + Q_{light}), \tag{3.19}$$

- Annual heat consumption to heat buildings:

$$Q_h^a = Q_h^w + Q_h^e, \tag{3.20}$$

where Q_h^w – annual water consumption to heat the buildings during working hours;

$$Q_h^w = 3600 \cdot 10^{-6} \cdot Q_h T n_d n_{at}, \tag{3.21}$$

where T – conversion factor from maximum heat consumption to the average heat consumption during heating season of the operation time;

$$T = \frac{t_i - t_e^{av}}{t_i - t_e}, \tag{3.22}$$

where t_e^{av} – average temperature of the external air during the heating season, t_{out}^{av} = - 4,7 ^{0}C;

n_d – number of working days during the heating season, n_d = 184 days;

n_{at} – active time of the shop a day, n_{at} = 8 hour/day;

Q_h^e – annual heat consumption during extra heating:

$$Q_h^e = 3600 \cdot 10^{-6} \cdot \sum Q_l \frac{t_f - t_e^{av}}{t_f - t_e} (24 n_h - n_d n_{at}), \tag{3.23}$$

where t_f – air temperature in the shop during idle time, t_f = 5 ^{0} C

n_h – number of days during the heating season, n_h = 243 days

2.3.3.2 Heat consumption for ventilation

- Heat consumption to heat air extracted from the building by air vents is calculated by:

$$Q_{ven} = y_{ven} V (t_i - t_e), \tag{3.24}$$

where y_{ven} – heat rate for ventilation; y_{ven} = 0,52 Ws/s*m^3 ^{0}C;

- Annual heat consumption for ventilation is:

$$Q_{ven}^a = Q_{ven} \cdot 3600 \cdot 10^{-6} \cdot \frac{t_i - t_e^{av}}{t_i - t_e} n_h n_{at}, \tag{3.25}$$

2.3.3.3 Heat consumption for hot-water supply

- Average daily heat consumption for hot-water supply is as follows:

$$Q_{hw} = amc(t_{hw} - t_{cw}), \tag{3.26}$$

where a – hot-water consumption rate at t =60 ^{0}C for all the buildings per unit measure, a = 0,07 liter/day (per 1 tap);

m – number of taps, m = 4 taps;

c – heat capacity of water, c = 4190 Ws/kg*^{0}C

t_{hw} – temperature of hot water, t_{hw} = 60 ^{0}C;

t_{cw} – temperature of cold water, t_{cw} = 5 ^{0}C;

- Annual water consumption for hot-water supply is calculated as follows:

$$Q_{hw}^{a} = Q_{hw}\left[n_h + \varphi_{hw}^{s}\frac{t_{hw}-t_{cw}}{t_{hw}-t_{cw}^{w}}(n-n_h)\right]10^{-6}, \quad (3.27)$$

where φ_{hw}^{s} – coefficient taking into consideration water consumption for hot-water supply during summer, φ_{hw}^{s} = 0,8 MWs/year;

t_{cw}^{w} – temperature of cold water in winter, t_{cw}^{w} = 10 ^{0}C;

n – number of days a year, n = 366 days.

- Total heat consumption is found by:

$$Q^{a} = Q_{h}^{a} + Q_{ven}^{a} + Q_{hw}^{a}, \quad (3.28)$$

It is necessary to convert the units of measurement for total heat consumption to Gigacalories because payment will be made in these units. The following formula (3.29) is used:

$$Q_{Gcal}^{a} = \frac{Q^{a}}{4{,}2\cdot 1000}, \quad (3.29)$$

2.4 Economic calculations

This section contains the following calculations:

- **Capital investments** (Table A.4.1 (Appendix A)). The total cost of the maching room overhaul (purchasing new equipment and a conveyor, as well as dismantling and installation) is calculated in Table A.4.1 (Appendix A). Capital investments will be considered within interval ±5%. This percentage shows that it is difficult to calculate a real cost of investment. The error will be then ±5% approximately.
- **Costs (*C*) of raw materials, primary and secondary materials** (Table A.4.2 (Appendix A)) are calculated by formula:

$$C=MP \quad (5.1)$$

where M – a material required for the production program;

P – price of the material taken from Internet.

The interval of possible error is taken ±5% as well.

- **Water, hot water and electrical power charges** are calculated similarly (Table A.4.3 (Appendix A)). The consumption of water and electrical power can be more or less if to compare to calculated value. The interval of possible error is taken ±5%
- **Nominal working time of machines** (Table A.4.4 (Appendix A))
- **Working time of a worker for 2004** (Table A.4.5 (Appendix A))
- **Salary accounting** for primary and auxiliary workers and technical staff

The number of workers and their designation is taken based on the equipment installed in the shop and machine utilization. One primary and one auxiliary worker usually operate one machine. Sometimes one worker operates two machines if machine utilization is low for these machines. The number of main workers can be changed. The error is taken approximately within an interval ±2 workers.

Number of working days is taken from Table A.4.5 (Appendix A).

Required number of working days is arrived at by multiplying the number of workers in a shift and number of working days.

The tariff is taken on the basis of the branch tariff agreement of the Russian Federation timber industry for 2004. However to enhance salary the tariff has been increased by 1.5 times and arrived at 12.5 rubles/hour for a worker of the first class, working under normal conditions. The calculation is presented in Table A.4.6 (Appendix A).

Salary accounting of the auxiliary workers and technical staff are presented in Table A.4.7 and Table A.4.8 correspondingly (Appendix A). Data relating to the wages of auxiliary workers and technical staff were taken from the factory. The annual tariff fund of wages is derived by multiplying the wage of the worker and number of working months per year.

- **Annual fund of wages**

A salary fund is presented in Table A.4.9 (Appendix A) taking into account a bonus rate of 100%, a regional bonus of 20%, a northern benefit of 50%, and percentage of additional salary K_{ad}, %. The percentage of additional salary is calculated using the formula:

$$K_{ad} = D_a / T_{ef}, \quad (5.2)$$

where D_a – days of absence from work (annual leave, training leave) (Table A.4.5 (Appendix A));

T_{ef} – number of effective working days (Table A.4.5 (Appendix A))

- **Depreciation of equipment**

A depreciation calculation is carried out on installed and exploitable equipment (Table A.4.10 (Appendix A)). The annual depreciation payment for the building is 8,001 rubles/year.

The depreciation rate of machines is taken to be 8,3%. To calculate depreciation it is necessary to:

1. determine the total combined value of the installed machines, unaccounted equipment and exploitable equipment (Table A.4.1 (Appendix A));
2. multiply the depreciation rate by this value.

- **Maintenance and operational costs of equipment**

The calculation is presented in Table A.4.11 (Appendix A). Depreciation of equipment is taken from Table A.4.10 (Appendix A). The wages of auxiliary workers is taken from Table A.4.9 (Appendix A).

Uniform social tax includes: assessments to pension fund – 28%, assessments to social insurance – 4%, and medical insurance – 3.6%.

3.8% is taken from the wages of auxiliary workers for social insurance against accidents and occupational diseases. Other expenses relating to maintenance and the use of basic assets include: services of a service shop and the costs of lubricating and cleaning materials. These expenses add up to 25% and 15% respectively of the salary of the adjuster. Assessments to current repairs add up to 40% of the salary of the repair-man (Table A.4.7 (Appendix A)). Assessments to major repairs of equipment add up to 4.37% of the cost of the equipment (Table A.4.10 (Appendix A)).

- **Machining workshop expenses**

The calculation is presented in Table A.4.12 (Appendix A). The salary of the technical staff is taken from Table A.4.9 (Appendix A). Maintenance costs of the factory building are 4% of the cost of the building (Table A.4.10 (Appendix A)). Current and major repairs constitute 10% and 2,7% of the cost of the building respectively. Costs for labour protection amount to 600 rubles per worker, while other costs are 800 rubles per worker (main and auxiliary workers).

- **Shop cost of the double bed**

Basing on the cost calculations carried out above, the total cost is calculated in Table A.4.13.

The calculation includes:

- Cost of materials (Table A.4.2 (Appendix A))
- Transport-storage expenses (8% of the cost of materials)
- Electricity, water charges (Table A.4.3 (Appendix A))

- Main and additional salary of the main workers (Table A.4.9 (Appendix A))
- Maintenance and operational costs of equipment (Table A.4.11 (Appendix A))
- Machining workshop expenses (Table A.4.12 (Appendix A))
- Shop cost is calculated as the sum of the above costs.

- **Plan of sales outcome**

The plan of sales outcome is presented in Appendix A Table 4.14. Shop profit is taken as 20% from shop cost. Profitability is an equal quotient from the division of shop profit and shop cost.

- **Net profit calculation**

To determine net profit it is necessary to subtract a income tax from the financial income. The income tax for enterprises is 24% from the sum of the financial income. Total profit is calculated as the sum of the net profit and the depreciation assessments.

The calculation is presented in Appendix A Table 4.15.

- **Project performance evaluation**

Capital investments are taken from Appendix A Table A.4.1. Sales are taken from Appendix A Table 4.15 and distributed equally from the second month of the production.

Indicators of performance evaluation are provided in Table A.4.17. These economic indicators of viability are used to create a finance project profile (Figure 3). To derive the Internal Rate of Return a graphical method is used (Figure 4).

- **Price formation**

Price is formed by adding shop costs and profit, which the company would like to receive.

2.5 Investigation of deformations emerging in combined glulam panels made from pine and spruce lamellas under conditions of variable humidity

2.5.1 Material

Investigation was conducted at the ”Dammers” company in Arkhangelsk, Russia.

“Dammers” put at the investigation’s disposal lamellas from pine and spruce species. These lamellas were designated for glued squared beams manufacture, which are used in window and door production. The moisture content of the material was 8 %. There are some requirements for the construction of laminated beams. The main requirement concerns the arrangement of growth rings. It should be radial or semiradial in outward layers. Beams without knots with a semiradial arrangement of growth rings were chosen for investigation.

"Dammers" uses glue based on polyvinyl acetate dispersion for the manufacture of glued squared beams. Glue properties are listed in Appendix A Table A.5.2.

2.5.2 Description of the investigation

Blanks from pine (43x18 mm) and spruce (44x18 mm) are used in the investigation. Adhesive was Rakoll-E*WB0301. Common pine and spruce were cut in the Arkhangelsk region in 2003. The blanks were dried to a MC of 8 %. The blanks of the pine had less cross section due to the fact that the saws were not installed in an identical manner during sawing of the pine and spruce blanks. This had an effect upon the dimensions of the glulam. They had different widths. Planed lamellae were coated with adhesive on their faces and laid parallel to one another in a jig, the whole assembly being clamped until the adhesive set. The following operations were made during panel production:

- Selection of lamella by species of wood
- Selection of lamella by fibre direction in a cross section
- Arrangement of the glulam: four panels from alternate lamella, a pine lamella following a spruce lamella, one panel of pine and one of spruce. Every panel consisted of four lamellas.
- Pressing in the jig
- Sanding of the panels
- Listing of the panel ends

The glulam of type I is only considered in this investigation. The ready panels were used in the tests carried out by scheme (Table 5.3). There were four observations in each test, and two observations with panels from pine and spruce lamellas. These two observations were needed to compare deformation changes occurring in combined panels during a humidity drop in the air.

Test №1 was conducted with uncoated panels and Test №2 with panels preliminarily coated with a polyurethane prime coating and polyurethane varnish from the firm Akzo Nobel. To obtain a reliable result under the given conditions it is important to make tests by scheme given in Table 5.4.This is impossible in this investigation due to the scarcity of given material.

To implement the two tests the panels were cut into two parts. Dimensions of these panels were 150x170 mm. The first half of cut panel was used in Test №1 and the second one in Test №2 accordingly. The ambient conditions of the panels were changed to in order to change the panel's moisture contents. For this they were kept in typical household conditions for one month, and in outdoor conditions for one day.

The profile of each panel was drawn using points. To define the points the glulam was put on a horizontal plane. The degree of curvature of the side faces in 4-5 points was measured by a gauge stick. The thickness of the panel was then measured by micrometer MC all-Union State Standard AUSS 6507-60. Profiles were drawn for panels containing different amounts of moisture. The measuring points were filled in Appendix A Tables A.5.4 and A.5.5.

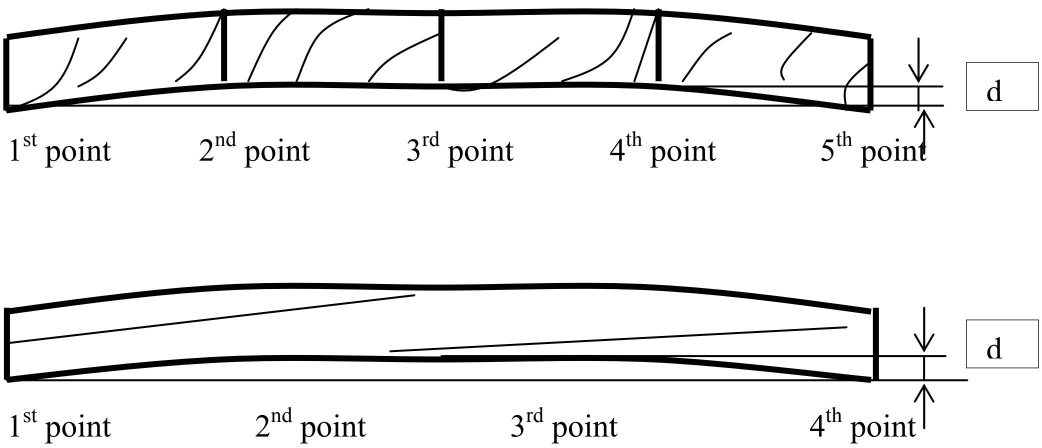


Figure 5.4 The points at the different sides of the panel for measurement by gauge stick

Table 5.3 Tests were conducted by the scheme below

test №	Factor A	-	Factors B & C					
			B – combine panel		B – panel from pine		B – panel from spruce	
			C_1 W=7.2%	C_2 W=9.2%	C_1 W=7.2%	C_2 W=9.2%	C_1 W=7.2%	C_2 W=9.2%
№1	Without lacquering	Number of observations	4	4	1	1	1	1
№2	With lacquering	Number of observations	4	4	1	1	1	1

Temperature of the surrounding air and relative humidity were determined by an aspiration psychrometer.

Determination of moisture content (MC) in the timber was carried out using the oven drying method according to all-Union State Standard 16483.7-71 with an error of 0,1%. For this method 3 specimens sawn from unpainted panels were used. Mass (*m*) of each specimen was measured by electronic scale with a balance error of 0,001 grams. Specimens were then oven-dried at 103±2 ^{0}C until constant mass (m_0). It is customary to express the moisture content *MC*, *%* of timber in terms of its oven-dry mass using the equation:

$$MC = \frac{m - m_0}{m} 100\,; \qquad (5.1)$$

The results are presented in Table A.5.3 (Appendix A).

The next step was making profiles. The panels were then kept outside for one day. Ease and speed of operation were selected in favour of extreme accuracy, so moisture constants were assessed by electric moisture meter EM-2k with an error of ±1,5 %. The pair of probes was inserted parallel to the grain direction.

The panel's profiles were compared with a model. The model was an ideal panel with the proper geometrical shape, the sides of which are parallel.

3 Results

3.1 Marketing results

All potential consumers are broken down into the segments (Fig. 3.1) but only some of them will be buyers of our commodity. Hence it is vital to select the segment that will be more likely to purchase the proposed set of bedroom furniture. Two segments A and B are selected. In our case six left squares are eliminated (Fig.3.1) because these are consumers who have a low monthly income per family member. Then six upper squares are eliminated, where the people are more than 55 years of age, because the possibility of there being a significant percentage of customers from this segment is low. Younger people, under 25 years of age, are similarly not included in our investigation. Young people as a rule live with their parents if they aren't married, or are not part of a couple, and many of them do not have a steady income; thus this segment of the population can be disregarded. The main population segment of interest is the 25-55 age-group who have a high average monthly income, and who are ready and wish to change their bedroom surroundings to a modern style.

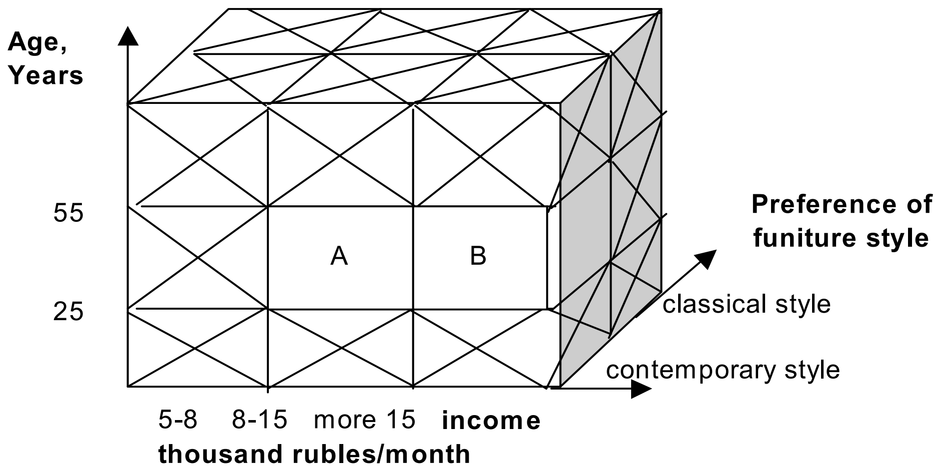


Figure 3.1 Sketch of market segmentation

Survey results are presented in Appendix A Tables A.1.1-A.1.3.

The survey indicated that 18 % of the people surveyed would like to buy a set of bedroom furniture. Out of these, 83.2 % would like to purchase the sets of bedroom furniture from solid wood, and 86.7 % – in the contemporary style. Opinions concerning what type of wood to use were mixed. The surveyed people preferred in equal degree the three species of wood pine, oak and cherry; while another 20 % offered their own variants. Summary data used to determine the annual demand for sets of bedroom furniture can be found in Appendix A Table 1.3.

Regarding the overall survey results, 18 % of those surveyed would like to buy a set of bedroom furniture, 19 % - a set of kitchen furniture and 16 % - a set of living room furniture. For the future, the Arkhangelsk Plywood Factory should take into account that kitchen furniture is in slightly greater demand. Those residents of Arkhangelsk, Novodvinsk and Severodvinsk who are willing to buy furniture made from solid wood represent a majority – 32 %. Furniture made from MDF came in second place at 16 %; and 10 % of survey participants are indifferent as to what material the furniture is made of. The most popular style is modern or contemporary style – 52 % of those surveyed. However, almost the same amount of people in both segments prefers the classical style. Oak is the most popular among other species of wood. The most important characteristic for potential buyers is quality and then design, followed by ecological safety, colour, the area occupied by furniture, the price and, the furniture-manufacturing firm.

Market capacity is taken 6% for sets of bedroom furniture. Thus the monthly program is 13 sets of bedroom furniture, or 156 sets a year.

3.2 Technical results

Functional structure of the set of bedroom furniture is shown in Table 3.1.

Table 3.1 Functional structure of the set of bedroom furniture

Structure	Items, pieces
Double bed	1
Bedside table	2
Chest of drawers with mirror	1
Folding wardrobe	1

According to the calculation (Table A.2.1 Appendix A) a material capacity of the each item was found. The double bed received conversion factor equal 1. The other items were reduced through this factor and the material capacities to find out how much material needed for the bed each item had. We need to produce 156 sets according to marketing research. That is in the material capacity is 800 double beds. The reduced program for the whole range of items was calculated in the same order and is given in Appendix A Table A.2.2. The reduced program is taken as 2,000 double beds.

An assembled representation of the double bed can be found in Figure 3.2. The design of the set was depicted in the working drawings (demi-A1 size): an overall view of the item, and a detailed drawing of the item in two drawings.

In the project equipment of domestic producers will be selected, because it is cheaper. The next criterion is that equipment should be modern. It is not necessary to have a big capacity of installed equipment, because the factory is going to manufacture furniture orienting on local market, but it should be modern. Modern equipment is implied good quality and long life of the machine. However, during some treating processes we will take into account foremost quality not only an amount of money spent. For example, then to install one two-sided planer is better to install one-sided facer and one-sided planer. Then the quality of the planks will be much better and the replacement and balancing of tools will be much easier /8/. The sanding process is possible to accomplish nowadays at multiple-purpose sander /8/. It allows dismantling two sanders and installing just such one.

Some machines will not be dismantled, because they are still not obsolete, thus new types of machines should fit to these machines by capacity. It is no use to install an automatic gluing machine, because the speed is very high and acceptable only for big factories. Thus a simple gluing machine with manual feed is sufficient to work out production.

Longitudinal cutting of the lumber can be work out at two machines. They exist at the "Arkhangelsk Plywood Factory". The first machine edges the lumber and the second cuts into the boards of necessary width. But all these two machines can be replaced by one machine. This machine must have automatic feeding and enough amount of disk saws.

3.2.1 Engineering process following reconstruction of the machining workshop

1. Timber cutting
   Crosscutting of the bars with cutting of the defective parts will be performed by crosscut machine ZST-01. Flat and deep cutting will be made by ripsaws ZDK-5 and ZA-2A.
2. Base forming is to be initiated after crosscutting at one-sided facers SF4-1A or SSF6-1.
3. Dimension moulding is carried out at four-sided moulder S25-4-UHL4.
4. It is then necessary visually to select lamellae depending on their growth rings before gluing. This will be performed manually at the work table.

5. Gluing of the lamellae in the glulam panels will be carried out using the cold method. The glued panels should not be stored longer than one day. Because the strength of the glue line and form stability of the panel will deteriorate after 24 hours storage.
6. The final processing of the glulam panels is next:
   1. Base formation will be at the one-sided facer SSF6-1;
   2. Thicknessing will be performed at the one-sided planer SR8-10;
   3. Marking-out of the panel to obtain partially-finished products and simultaneous quality rating will be conducted at the work table;
   4. Filing of the glulam panels will be performed by the disk saw Z6-2;
   5. Milling around the perimeter of the partially-finished products will be performed by SFU-1.
7. Milling makes it possible to obtain various part profiles. Stiles and spreaders are to be milled at the milling machine SFU-1. Tenons of the frame are formed at the milling machine with tenon head FSSH-1A. This machine can be used for making a wide variety of milling works.
8. Drilling of holes and grooves is to be done at the drilling-grooving vertical machine with automatic feeding machine SVA-2 and drilling-grooving horizontal machine SVPG-1R.
9. Sanding is required before finishing. Surface roughness should be Rm_{max}=16 mcm. To sand faces and edges the multi-purpose SHlPS-Kombi sander will be used; to sand different assemblages and parts the SHlDB drum sander machine will be used.

The reconstruction activities are represented as the plan of equipment arrangement.

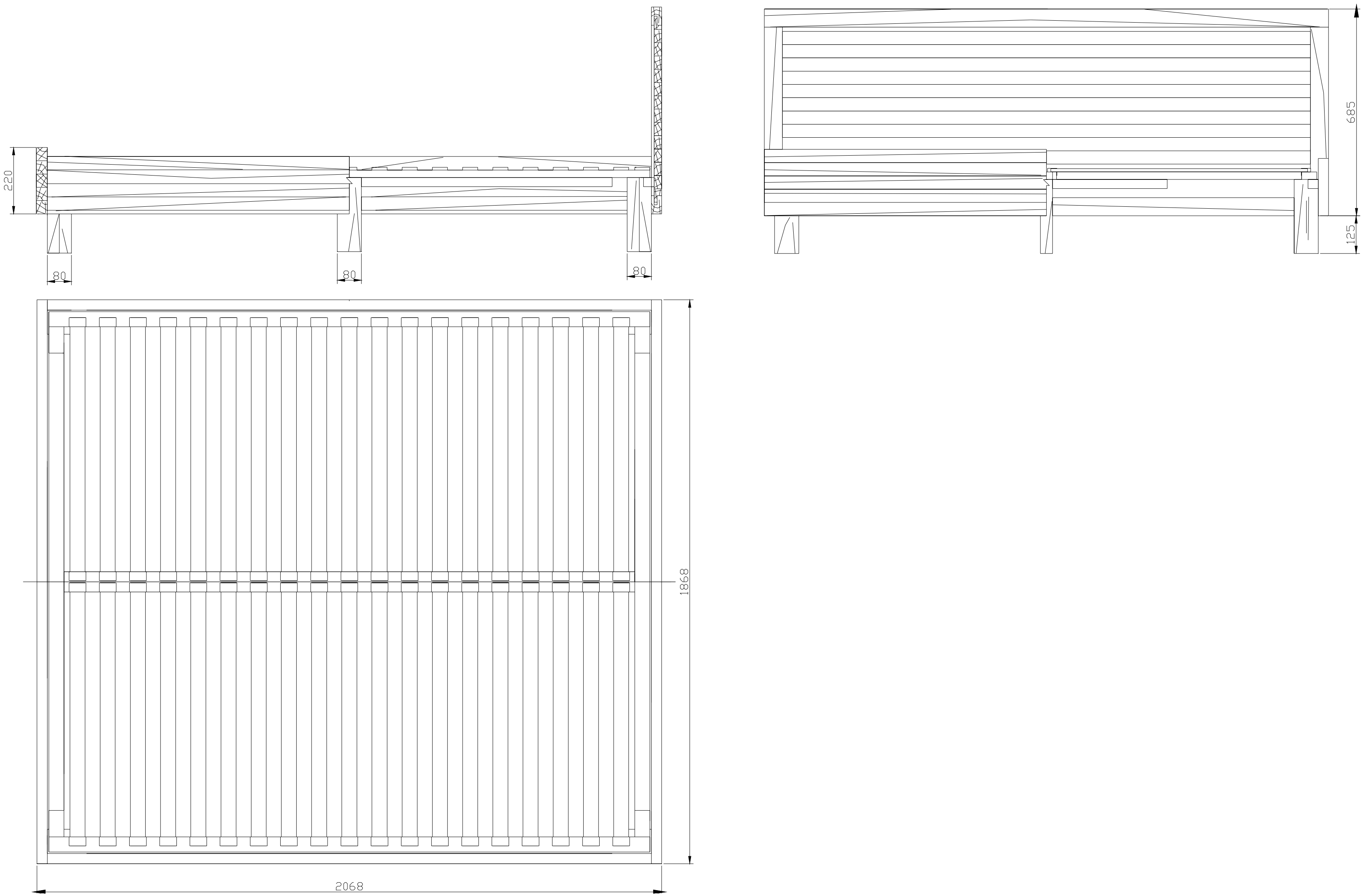


Figure 3.2 Assembled representation of the double bed

3.3 Economic results

Capital investments are as follows:

K =(1254,27±62,71)+(16,347±0,82)+(65,516±3,28) = 1336,133±66,81 rubles

Net profit is as follows: (1397,622±70,994)/12=116,469±5,916rubles/month.

The calculation of the shop costs are represented in details in Table 3.1. Economic results are represented in Tables 3.2 and 3.3.

Table 3.1 Shop cost of the production program (2000 double beds)

Description of expenses	Sum, thousand rubles
Raw materials and materials	1859,167±92,958
Transport-storage expenses (8%)	436,733±21,837
Electricity, water charges	425,550±21,278
Main and additional salary of the main workers	1745,213±174,521
Uniform social tax (35,6%)	621,296±62,129
Assessments to social insurance against accidents and occupational diseases (3,8%)	66,318±6,632
Maintenance and exploitation costs of equipment	1200,087±14,674
Workshop expenses	1327,362
Shop costs	7681,726±394,029

Table 3.2 Technical and economic activities

Activities	Units	Value	Value
Production program	Pieces	1	2000
Capital investments	Thousand rubles	0,668±0,033	1336,133±66,81
Fund of wages	Thousand rubles	1,576±0,087	3151,373± 174,521
Number of staff	Persons	29±2	29±2
Monthly average salary of 1 worker	Thousand rubles	9,056	9,056
Shop cost	Thousand rubles	3,84±0,197	7681,726±394,029
Financial income	Thousand rubles	0,768±0,039	1536,345±78,806
Income tax	Thousand rubles	0,184±0,001	368,723±18,913
Net profit	Thousand rubles	0,584±0,030	1167,622±59,893
Profitability	%	20	20

Table 3.3 Measures of performance evaluation

Description	Units	Value
Cumulative Cash flow in September, 2005	Thousand rubles	177,958
Net Present Value in September, 2005	Thousand rubles	68,358
Internal Rate of Return	%	1.8
Maximum Cash Exposure in August, 2004	Thousand rubles	1336,133±66,81
Payback	Months	13.5
Profitability Index in September, 2005	-	1.04

Figures 3.1 and 3.2 show finance profile of the project and internal rate of return.

The machining shop costs are 3,850±0,200 rubles and costs for finishing and assembly works are taken approximately 2,000±0,500 rubles. Then price of the bed is 5,850±0,700 if profitability is assumed as 20 %. The prices of the other items of the set are presented in Table A.4.16. Appendix A.

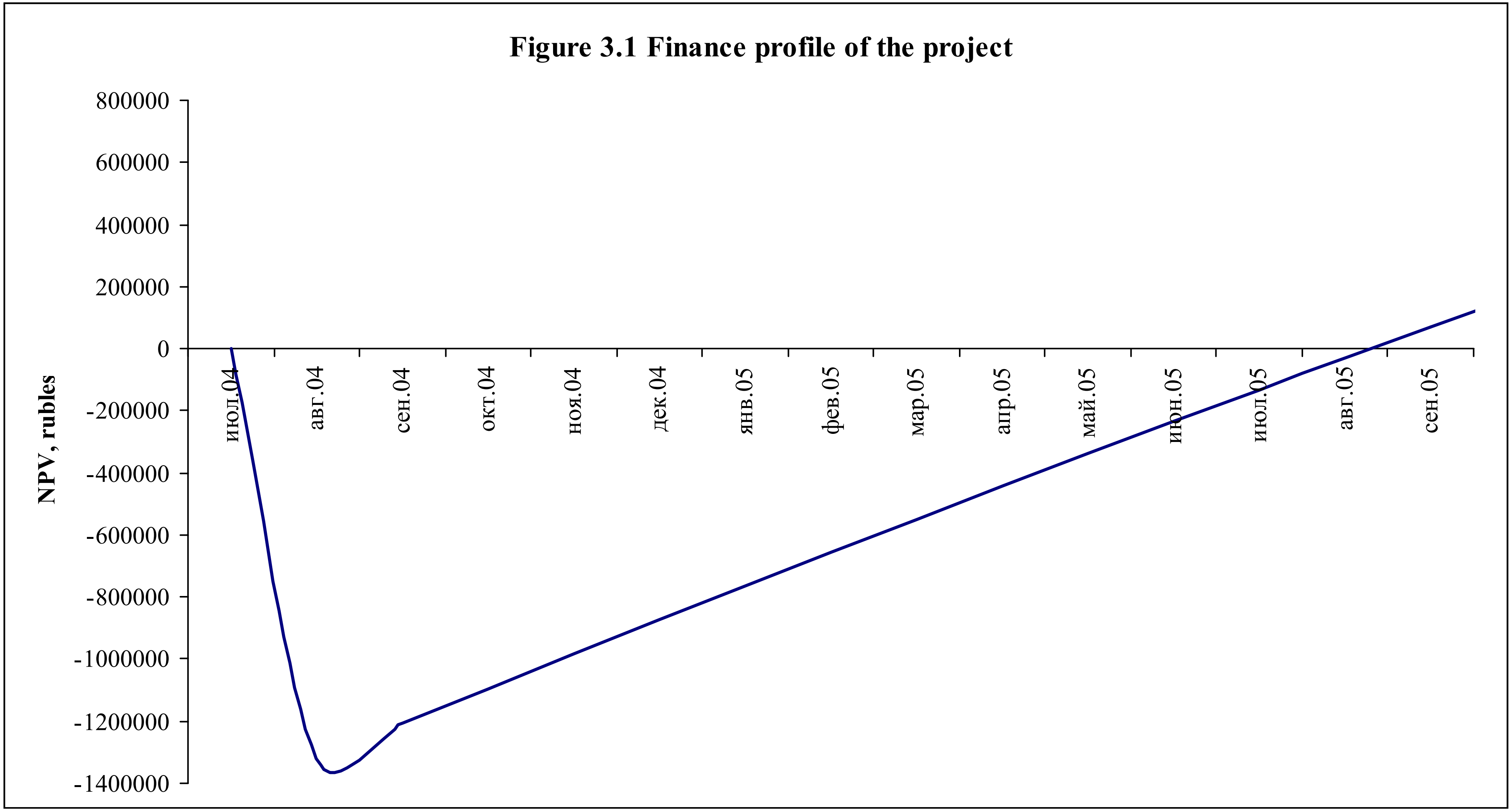
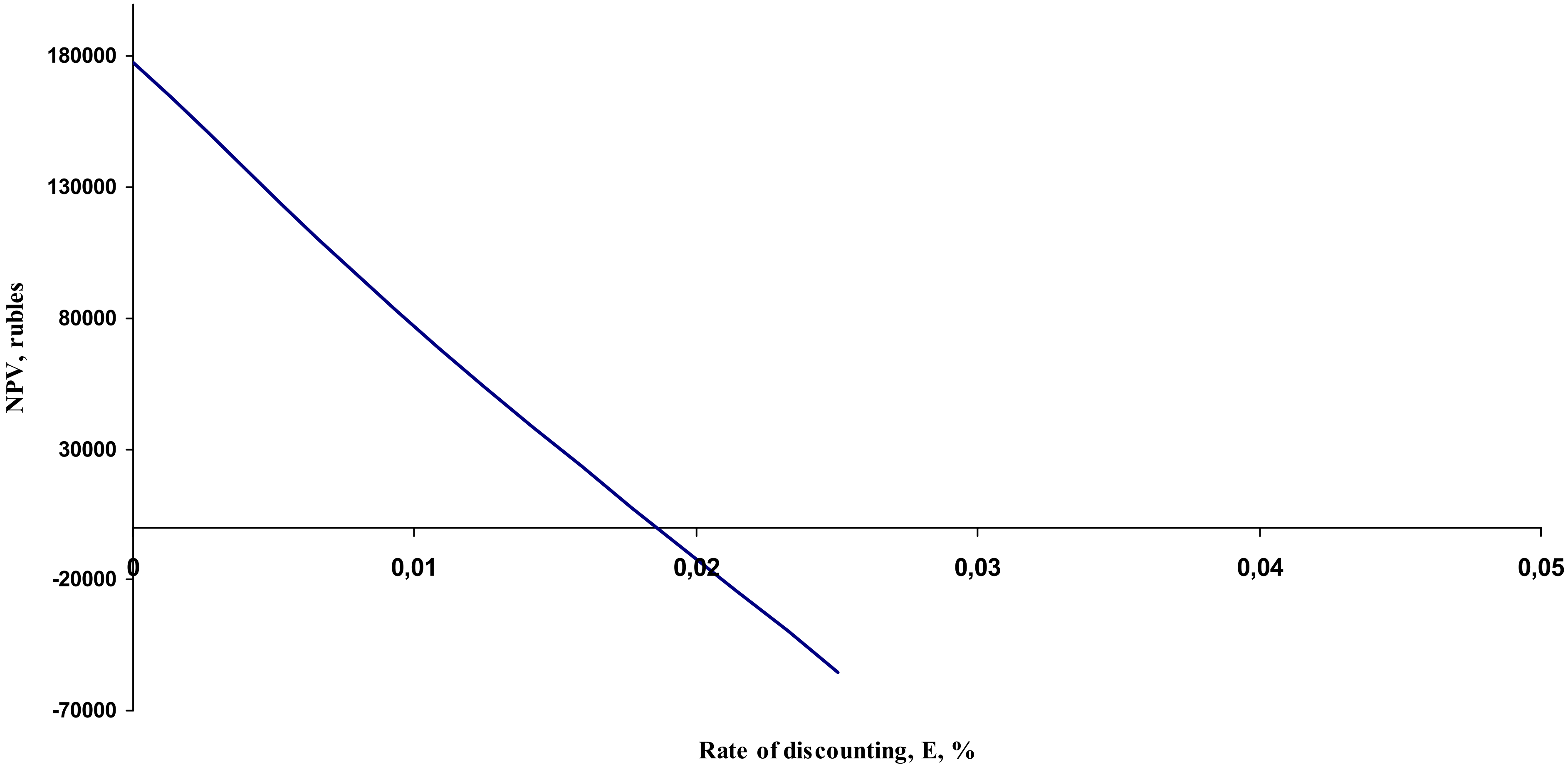


Figure 3.1 Finance profile of the project
NPV, rubles
800000
600000
400000
200000
0
-200000
-400000
-600000
-800000
-1000000
-1200000
-1400000
июл.04
авг.04
сен.04
окт.04
ноя.04
дек.04
янв.05
фев.05
мар.05
апр.05
май.05
июн.05
июл.05
авг.05
сен.05

Figure 3.2 Internal rate of return



3.4 Results of the investigation

Drawings of profiles for ends and longitudinal edges of the glulam panel give a presentation of panel's deformations emerged in the conditions of variable relative humidity (Appendix B Figures B.1- B.3).

The profiles for ends and longitudinal edges of the glulam give a pictorial presentation of a glulam's deformation under conditions of variable relative humidity. One can note the regularity in the behaviour of the combined glulam made up of spruce and pine lamellas, in the respect that under conditions of RH 35% and EMC 7.2 % the glulam had a concave profile, but when the moisture content increased to 9.2 % the profile became convex (Figure B.1-B.2 (Appendix B)). Moisture increase occurred as a result of placing the panels in the outside air where the temperature was 11 ^{0}C and relative humidity approximately 88 %.

The second test indicated that protective and decorative coating is a good protection against moisture absorption by timber (Figure B.3 (Appendix B)). The lines of upper and bottom edges during alteration of the moisture content from 7.2 % to 9.2 % did not significantly change their position in the area.

4 Conclusions and Discussion

The set of bedroom furniture was made by some modifications of a set "Logics". This set is easily produced and corresponds standards given in /4/.

The marketing investigations determined the number of sets of bedroom furniture that should be manufactured (156 sets). However, the shop produces a number of types of woodwork, thus the production program was 2,000 double beds. This gave an opportunity to calculate how much material is required for production. The calculation was necessary to determine the quantity of main raw materials (wane-edge lumber) not only for cost calculation but also to ensure that a drying kiln is able to dry the required number of the lumber. To implement the annual production program the capacity of kilns is sufficient.

Analysis of the engineering process at the machining workshop indicates that, in order to render the new production process, some of the equipment must be replaced by more modern types, and that a floor-type conveyor system should be installed. The total cost of this overhaul (purchasing new equipment and a conveyor, as well as dismantling and installation) is 1300,000 rubles. The author of this thesis recommends installing domestic equipment as it is less expensive than imported equipment, taking into consideration the current purchasing capacity of the operation, and also that specialists be engaged to install and fine-tune the new machinery.

Based on the amount of equipment required for the proposed production, it is estimated that 20±2 fully-dedicated workers are needed to implement the program. One of the tasks of the project was to increase employee salary by a factor of 1.5. As result the average wage is 9,000 rubles.

The ultimate cost of the set is approximately 30,000±0,300 rubles. Therefore it was assumed that a 20% return from the machining shop costs meant that the manufacture of solid wood furniture will be profitable. However, more than 60 % of those surveyed people would spend more 30,000 rubles on a new set of bedroom furniture. This suggests a lower price limit for the furniture can be established.

The finance profile of the project (Figure 3.1) indicates a payback period of 13.5 months and by September the net profit is to be 68,000 rubles. It should be noted that a production program of 156 sets/year of bedroom furniture will completely pay back the investment. The manufacture of other kinds of cabinet furniture will bring a real net profit in the future.

Basing on economic calculations reconstruction expenses will be recovered in 13.5 months, assuming the enterprise is able to provide a stable level of sales and net profit earning at a rate of 116,000 rubles/month. Internal Rate of Return has been calculated at 1.8 % a month, exceeding the rate of discounting E=1.1 % a month, leading to a positive conclusion regarding project viability. Therefore the reconstruction of the machining workshop at the furniture plant of the Arkhangelsk Plywood Factory Joint Stock Company is economically feasible.

The degree of glulam deformation is dependent on shrinkage and swelling, which are different for pine and spruce. Shrinkage and swelling in radial and tangential direction are more pronounced in pine than spruce (Table A.5.1 (Appendix A). Therefore, the percentage of edge arc change is more in the combined glulam and spruce glulam in comparison to glulam made from pine lamellas. When glulam lost moisture they had one direction, when they absorbed moisture it had another direction. The presence of mixed species in the same glulam led to an increase in bending deflection. The behaviour of the spruce panel is difficult to assess unambiguously as the percentage of edge arc change is approximately the same as that of the combined glulam. Stresses emerging during shrinkage and swelling in all cases caused twisting of the glulam. Twisting has not been considered in the investigation but it had an influence on the profiles.

The preliminary investigation suggests that deformation in combined glulam and spruce glulam is greater than that of pine glulam. Coating could prevent deformation. It is necessary to collect more observations to draw more definitive conclusions. This leads to that the risk to produce combined glulam is almost equal to the risk to produce spruce glulam.

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Appendix A

Table A.1.1 Questionnaire Results

Question	Segment A (25 to 55 years of age) (From 8000 to 15000 rubles.)	Segment B (25 to 55 years of age) (More than 15000 rubles.)	Total	% from total number of people
1	2	3	4	5
Surveyed people	44	29	73	73
A set of bedroom furniture	11	7	18	18
A set of living room furniture	9	7	16	16
A set of children room furniture	5	3	8	8
Furniture for the hallway	5	2	7	7
A set of kitchen furniture	12	7	19	19
Your variant	3	2	5	5
Solid wood	19	13	32	32
Particleboard	1	3	4	4
Plywood	2	2	4	4
MDF	13	3	16	16
Other materials	6	1	7	7
It doesn’t matter	5	5	10	10
Pine	7	5	12	12
Oak	16	12	28	28
Cherry	9	7	16	16
Your variant	14	3	17	17
Less than 15000 rubles.	-	-	-	-
From 15000 to 20000 rubles.	4	3	7	7
From 20000 to 25000 rubles.	14	12	26	26
From 25000 to 30000 rubles.	11	9	20	20
More than 30000 rubles.	16	4	20	20

Continuation of Table A.1.1

1	2					3					4					5				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Ecological safety	0	6	5	11	22	1	1	3	4	20	1	7	8	15	42	1	7	8	15	42
Quality	1	0	1	5	37	0	0	0	5	24	1	0	1	10	61	1	0	1	10	61
Colour	0	0	11	10	23	1	1	7	14	6	1	1	18	24	29	1	1	18	24	29
Design	0	1	7	10	26	0	1	2	6	20	0	2	9	16	46	0	2	9	16	46
Area occupied by furniture	1	1	13	13	16	1	2	11	6	9	2	3	24	19	25	2	3	24	19	25
Manufacturing firm	17	8	10	4	5	14	1	5	5	4	31	9	15	9	9	31	9	15	9	9
Price	4	2	12	17	9	0	0	9	4	16	4	2	21	21	25	4	2	21	21	25
Classical ”Royal”	11					10					21					21				
Contemporary	33					19					52					52				
Service term of furniture, years.	12					10					11					11				

Table A.1.2 Questionnaire Results

Question	Segment A (25 to 55 years of age) (From 8000 to 15000 rubles.)	Segment B (25 to 55 years of age) (More than 15000 rubles.)	Total	% from total number of people
Solid wood	10	5	15	83,2
Particleboard	-	-	-	-
Plywood	-	1	1	5,6
MDF	1	-	1	5,6
Other materials	-	-	-	-
It doesn’t matter	-	1	1	5,6
Pine	3	1	4	26,7
Oak	3	1	4	26,7
Cherry	1	3	4	26,7
Your variant	3	-	3	20
Less than 15000 rubles.	-	-	-	-
From 15000 to 20000 rubles.	-	-	-	-

Continuation of Table A.1.2

From 20000 to 25000 rubles.	2	1	3	20
From 25000 to 30000 rubles.	1	2	3	20
More than 30000 rubles.	7	2	9	60
Classical "Royal"	2	-	2	13,3
Contemporary	8	5	13	86,7

Table A.2.1 Calculation of the reduced production program

Item description	Production program, pieces/year	Material capacity of the article, m^3	Conversion factor	Reduced program, pieces/year
Double bed	156	0,09863	1	156
Bed-side table	312	0,04759	0,482	152
Chest of drawers with mirror	156	0,12933	1,311	207
Folding wardrobe	156	0,17908	1,816	286
			Total	800

Table A.2.2 The reduced program

Item description	Production program, pieces/year	Material capacity of the article, m^3	Conversion factor	Reduced program, conventional unit/year
1	2	3	4	5
Double bed	800	0.09770	1	800
Upholstered stool	100	0.015	0.154	15.353
Stool	100	0.015	0.154	15.353
Upholstered stool	100	0.015	0.154	15.353
Dinner table	100	0.06	0.614	61.412
Dinner table	100	0.06	0.614	61.412
Kitchen set	100	0.11	1.126	112.590
Table	100	0.065	0665	66.530
Door frame 21-7 milled	50	0.16	1.638	81.883
Door frame 21-9 milled	50	0.16	1.638	81.883

Continuation of Table A.2.2

1	2	3	4	5
Door frame 21-9 decor	50	0.16	1.638	81.883
Door frame 21-7 milled	50	0.16	1.638	81.883
Door frame 21-8 milled	50	0.16	1.638	81.883
Door frame 21-9 enamel	50	0.16	1.638	81.883
Door frame 21-13 milled	50	0.16	1.638	81.883
Window frame 12-15	50	0.105	1.075	53.736
Window frame	50	0.105	1.075	53.736
Window frame 15-18	50	0.105	1.075	53.736
Bed for child	50	0.04	0.409	20.471
Table for phone	50	0.02	0.205	10.235
Shelves	100	0.039	0.399	39.918
Magazine table	100	0.04	0.409	40.942
Half-finished product for cushioned furniture	100	0.021	0.021	2.149
Total	2,400	2.014	-	1,996

Table A.2.3 Specifications of double bed

Conventional signs	Designation of assembly units and details	Amount of details in item, pieces.	Material, species of wood	Grade	Dimensions of details, mm		
					Length	Width	Thickness
1	2	3	4	5	6	7	8
01.00.00	Headboard	1	-	-	1860	685	34
01.01.00	Frame	1	-	-	-	-	-
01.01.01	Stile	2	Pine AUSS 8486-86	I-IV	625	60	34
01.01.02	Spreader	2	Pine AUSS 8486-86	I-IV	1860	60	34
01.02.00	Panel	1	-	-	1780	613	25
01.02.01	Dimension blank	14	Pine AUSS 8486-86	I-IV	1780	44	25
02.00.00	Footboard	1	-	-	1860	220	34
02.00.01	Dimension blank	5	Pine AUSS 8486-86	I-IV	1860	44	34
03.00.00	Bed frame	2	-	-	2000	190	34

Continuation of Table A.2.3

1	2	3	4	5	6	7	8
03.00.01	Dimension blank	9	Pine AUSS 8486-86	I-IV	2000	44	34
03.00.02	Bar left, right	2	Pine AUSS 8486-86	I-IV	1740	34	30
04.00.00	Bed grill	1	-	-	-	-	-
04.01.00	Frame	1	-	-	1990	1790	25
04.01.01	Spreader	2	Pine AUSS 8486-86	I-IV	1990	50	25
04.01.02	Stile	2	Pine AUSS 8486-86	I-IV	1790	50	25
04.01.03	Inner rail	1	Pine AUSS 8486-86	I-IV	1990	67	25
04.00.01	Leg	1	Pine AUSS 8486-86	I-IV	270	80	40
04.00.02	Bar	38	Plywood AUSS 3916.1-96	B/BB	850	50	10
04.00.03	Bar	2	Plywood AUSS 3916.1-96	B/BB	1515	50	10
05.00.00	Leg	4	-	-	245	80	80
05.00.01	Dimension blank		Pine AUSS 8486-86	I-IV	245	80	40
00.00.01	Bar	2	Pine AUSS 8486-86	I-IV	800	34	30

Table A.2.4 Calculation of the amount of timber-based materials required for the double bed

Production program: 2,000

Conventional signs № in the drawing	Designation of assembly units and details	Material, species of wood	Grade	Amount of details in article, pieces.	Dimensions of details, mm			Square, m^2 or Volume, m^3			Process allowance, mm			Repeat factor			Dimensions of dummies, mm			Standard thickness of the dummy, mm	Square, m^2 or Volume, m^3			Process losses, %	Square, m^2 or Volume, m^3 with process losses	Volume yield of the dummy from timber, %	Timber consumption for the program, m^2, m^3
					Length	Width	Thickness	One detail	Details in the item	Details for the program	For length	For width	For thickness	For length	For width	For thickness	Length	Width	Thickness		One dummy	Dummies in the item	Dummies for the program				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
01.00.00	**Head back**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
01.01.00	Frame	-	-	1	1868	685	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
01.01.01	Stile	Pine	I-IV	2	625	60	34	0,00128	0,00255	5,10000	20	14	6	2	2	1	1290	148	40	40	0,00764	0,00382	7,63680	3	7,86590	62	13
01.01.02	Spreader	Pine	I-IV	2	1868	60	34	0,00381	0,00762	15,24288	36	14	6	1	2	1	1904	148	40	40	0,01127	0,01127	22,54336	3	23,21966	62	37
01.02.00	Panel	-	-	1	1780	613	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
01.02.01	Dimension blank	Pine	I-IV	14	1780	44	25	0,00196	0,02741	54,82400	30	12	6	1	4	1	1810	147	50	50	0,01332	0,04663	93,25120	3	96,04874	62	155
02.00.00	**Foot back**	-	-	1	1868	220	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
02.00.01	Dimension blank	Pine	I-IV	5	1868	44	34	0,00279	0,01397	27,94528	30	12	6	1	3	1	1898	137	50	50	0,01304	0,02173	43,46420	3	44,76813	62	72
03.00.00	**Bed frame**	-	-	2	2000	190	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
03.00.01	Dimension blank	Pine	I-IV	9	2000	44	34	0,00299	0,02693	53,85600	30	12	6	1	3	1	2030	137	50	50	0,01395	0,04184	83,67660	3	86,18690	62	139
03.00.02	Bar left, right	Pine	I-IV	2	1740	34	30	0,00177	0,00355	7,09920	40	9	6	1	3	1	1780	117	40	40	0,00835	0,00556	11,12714	3	11,46095	62	18

Continuation of Table A.2.4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
04.00.00	**Bed grill**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
04.01.00	Frame	-	-	1	1990	1790	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
04.01.01	Spreader	Pine	I-IV	2	1990	50	25	0,00249	0,00498	9,95000	36	8	7	1	2	1	2026	115	32	32	0,00746	0,00746	14,91136	3	15,35870	62	25
04.01.02	Stile	Pine	I-IV	2	1790	50	25	0,00224	0,00448	8,95000	36	8	7	1	2	1	1826	115	32	32	0,00672	0,00672	13,43936	3	13,84254	62	22
04.01.03	Inner rail	Pine	I-IV	1	1990	67	25	0,00333	0,00333	6,66650	36	8	7	1	2	1	2026	149	32	32	0,00966	0,00483	9,65997	3	9,94977	62	16
04.00.01	Leg	Pine	I-IV	1	270	80	40	0,00023	0,00023	0,46000	20	8	4	4	2	1	1160	175	44	44	0,00893	0,00112	2,23300	3	2,29999	62	4
04.00.02	Bar	Plywood	B/BB	38	850	50	10	0,043	1,615	3230	0	0	0	1	1	1	850	50	10	10	0,043	1,615	3230	2	3294,6	85	3876
04.00.03	Bar	Plywood	B/BB	2	1515	50	10	0,076	0,152	303	0	0	0	1	1	1	1515	50	10	10	0,076	0,152	303	2	309,06	85	364
05.00.00	**Leg**	-	-	4	245	80	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
05.00.01	Dimension blank	Pine	I-IV	2	245	80	40	0,00013	0,00102	2,04800	20	8	4	4	2	1	1060	175	44	44	0,00816	0,00204	4,08100	3	4,20343	62	7
00.00.01	Bar	Pine	I-IV	2	800	34	30	0,00082	0,00163	3,26400	35	9	6	1	3	1	835	117	40	40	0,00391	0,00261	5,21975	3	5,37634	62	9
Total material consumption				Pine I-IV			m^3	0,02384	0,09770	195,40586	-										0,11240	0,15562	311,24374	-	320,58105	-	517
				Plywood FU			m^2	0,118	1,767	3533											0,118	1,767	3533		3603,66281,085		4240

Table A.2.5 Calculation of half-finished panels from plywood by cutting-to-length chart

Production program 2,000

№ of cutting-to-length chart	Dimensions of the standard panel, mm		Standard panel square, m^2	Dimensions of the half-finished panel, mm		Half-finished panel square, m^2	Amount of the half-finished panels in the item, pieces.	Amount of the half-finished panels in the item, pieces.		Square of the half-finished panels cut from the standard panel, m^2	Volume yield of the half-finished panel, %	Amount of the standard panels needed for the program, pieces	Amount of the half-finished panels got from the standard panel, pieces	Deviation from the complete cutting, pieces
	length	width		length	width			For program	Cut from the standard panel					
1	1525	1525	2,33	850	50	0,043	38	76000	38	1,615	69	2000	76000	0
				1515	50	0,076	2	4000	2	0,152	7	2000	4000	0
				-	-	-	-	-	-	1,767	76	-	-	-

Table A.2.6 Timber Specification

№	Timber	AUSS	Specie, type	Grade	Dimensions			Amount of the timber m^3 (m^2)
					length, m	width, mm	thickness, mm	
1	2	3	4	5	6	7	8	9
1	Wane-edge softwood timber	AUSS 8486-86	pine	I-IV	5	-	50	366
2	Wane-edge softwood timber	AUSS 8486-86	pine	I-IV	5	-	44	11
3	Wane-edge softwood timber	AUSS 8486-86	pine	I-IV	5	-	40	77
4	Wane-edge softwood timber	AUSS 8486-86	pine	I-IV	5	-	32	63
5	Plywood FU	AUSS 3916.1-96	FU	B/BB	1525	1525	10	331

Table A.2.7 Calculation of the glued surfaces

Glue type	Methods of agglutina-tion	Gluing	Description of details	Material of glued surfaces	Number of details in the item	Number of gluing surfaces in the item	Dimensions of the gluing surfaces, mm		Area of the gluing surface, m^2			
									Total	Including groups of complexity		
							length	width		I	II	III
PVA glue	cold	manually	01.02.01	Pine timber	14	1	1780	25	0,623	-	0,623	-
			02.00.01	Pine timber	5	1	1860	34	0,316	-	0,316	-
			03.00.01	Pine timber	9	1	2000	34	0,612	-	0,612	-
			05.00.01	Pine timber	4	1	245	80	0,078	-	0,078	-
-							Total		**1,630**	-	1,630	-

Table A.2.8 Calculation of adhesive consumption

Production program: 2000

Glue	AUSS	Unit	Methods of agglutination	Groups of complexity	Area of the gluing surface, m^2	Standard expense allowance of the glue, kg/m^2	Standard expense allowance for the item, kg	Glue consumption for the program, kg
PVA glue	AUSS18992-80	kg	cold	II	1,630	0,42	0,684	1369

Table A.2.9 Calculation of requirement for additional components

Component	AUSS, TC	Sizes, mm			Unit	Applied amount	
		length	width	thickness		For the article	For the program
Furniture hinges	ISO 9001	-	-	-	pieces	4	8,400
Furniture hinges	ISO 9001	42	14	2,5	pieces	4	8,400
Eccentric	2.3-A-06	-	25	-	pieces	4	8,400
Screws	AUSS 1144-80	25	4	4	pieces	4	8,400
Screws	AUSS 1144-80	20	4	4	pieces	8	16,800
Screws	AUSS 1144-80	20	2,5	2,5	pieces	10	21,000
Screws	AUSS 1144-80	50	5	5	pieces	16	33,600
Holders	-	-	-	-	pieces	76	159,600
Staples	-	-	-	-	pieces	228	478,800

Table A.2.10 Calculation of sandpaper requirements

Description of sanding material	Material of the sanding surface	Method of sanding	Description of detail, assembled units	Square of sanding, m^2	Standard expense allowance of sandpaper, m^2/m^2		Standard expense allowance of sandpaper for the article, m^2		Sandpaper consumption for the program, m^2	
					25-16	12-10	25-16	12-10	25-16	12-10
1	2	3	4	5	6	7	8	9	10	11
Sandpaper	Pine timber	Machine	Headboard	2,5	0,024	0,021	0,06	0,05	122,31	107,02
			Footboard	0,8			0,02	0,02	39,28	34,37
			Bed frame	1,5			0,04	0,03	72,96	63,84
			Leg	0,3			0,01	0,01	12,29	10,75
			Edges of the headboard	0,2	0,027	0,023	0,005	0,004	9,35	7,96
			Edges of the footboard	0,1			0,004	0,003	7,64	6,51
			Edges of the bed frame	0,3			0,01	0,01	14,69	12,51
			Total	5,7	-	-	-	-	278,5	243

Table A.2.11 Calculation of required equipment by standard time

Conventional signs	Number	Manufacturing operation							
		Crosscutting	Jointing	Longitudinal cutting	Thicknessing	Four-sided moulding	Selecting of lamellae	Gluing	Postpressing stage
		Equipment							
		ZST-01	SF4-1A	ZDK5-2	SR3-6	S25-4-UHL4	manually	KV2-3	VR-6
1	2	3	4	5	6	7	8	9	10
00.00.00	1								
01.00.00	1								
01.01.00	1								
01.01.01	2	55	8	24	4	8			
01.01.02	2	115	12	40	7	24			
01.02.00	1								○→
01.02.01	14	766	73	354	43	157	○→	○→	
02.00.00	1								○→
02.00.01	5	232	27	103	16	59	○→	○→	
03.00.00	2								○→
03.00.01	9	437	49	199	32	112	○→	○→	
03.00.02	2	46	9	29	6	22			
04.00.00	1								
04.01.00	1								
04.01.01	2	35	11	17	6	25			
04.01.02	2	31	11	17	6	22			
04.01.03	1	18	7	9	3	12			
04.00.01	1	10	4	6	2	3			
04.00.02	38								
04.00.03	2								
05.00.00	4								○→
05.00.01	2	81	32	48	15	25	○→	○→	
00.00.01	2	31	7	19	4	10			
Total		1856	250	865	144	479			

Table A.2.12 Calculation of required equipment by standard time

Conventional signs	Number	Manufacturing operation									
		Filling around perimeter of panel	Jointing	Thicknessing	Cutting-to-length	Milling around perimeter	Cutting of tenons	Drilling	Grooving	Sanding	
		Equipment									
		Z6-2	SSF6-1	SR8-10	Z6-2	SFU-1	FSSH-1A	SVPG-1R	SVA-2	SHlPS-Kombi	SHlDB
1	2	3	4	5	6	7	8	9	10	11	12
00.00.00	1										
01.00.00	1					83		27		361	
01.01.00	1										
01.01.01	2					15	15		310		42
01.01.02	2					36	26		660		162
01.02.00	1	19	25	24		51	60			254	
01.02.01	14										
02.00.00	1	13	25	24		12		27		151	
02.00.01	5										
03.00.00	2	26	55	51					30	279	
03.00.01	9										
03.00.02	2							47			
04.00.00	1										
04.01.00	1										
04.01.01	2						27				
04.01.02	2						26				
04.01.03	1						16		9		
04.00.01	1						9				10
04.00.02	38				255						552
04.00.03	2				26						32
05.00.00	4							46		262	30
05.00.01	2	11									
00.00.01	2							45			
Total		69	105	99	281	196	179	192	1009	1307	828

Table A.2.13 Machine utilization

Equipment type	Model	Required number of machine-hours for the program, machine-hour	Annual effective time schedule of machine's work, machine-hour	Calculated number of machines for the program	Selected number of machines	Percentage of machine utilization, %
1	2	3	4	5	6	7
Crosscut saw	ZST-01	1856	1913	0,97	1	97
Ripsaw	ZDK5-2	865	1913	0,45	1	45
One-sided facer	SF4-1A	250	1913	0,32	1	32
One-sided facer	SSF6-1	105	1913	0,06	1	6
One-sided planer	SR3-6	144	1913	0,08	1	8
Four-sided moulder	S25-4-UHL4	479	1913	0,25	1	25
Disk saw with manual feeding	Z6-2	350	1913	0,18	1	18
One-sided planer	SR8-10	99	1913	0,05	1	5
Milling machine	SFU-1	196	1913	0,10	1	10
Milling machine with tenoning head	FSSH-1A	179	1913	0,09	1	9
Drilling-grooving	SVPG-1R	192	1913	0,10	1	10
Drilling-grooving with automatic feed	CVA-2	1009	1913	0,53	1	53
Multi-purpose sanding machine	SHlPS-Kombi	1307	1913	0,68	1	68
Drum sanding machine	SHlDB	828	1913	0,43	1	43

Table A.2.14 Calculation of tools required for production program

№	Model of equipment	Number of machines, pieces	Description of tools	Number of tools applied to one machine, pieces	Magnitude of allowable sewing-up, mm	Duration of tool life, hour	Average tool reduction for one refile, mm	Percentage of breakage and unforeseen tool consumption	Required number of machine-hours for the program, machine-hour	Tool consumption, pieces	Required tools, pieces
1	ZST-01	1	Carbide-tipped circular saw	1	6	30	0,2	15	1856	2,426	3
2	ZDK5-2	1	Carbide-tipped circular saw	5	6	30	0,2	15	865	5,654	10
3	SF4-1A	1	Carbide-tipped jointer	2	8	40	0,2	5	250	0,658	4
4	SR3-6	1	Carbide-tipped jointer	2	8	40	0,2	5	144	0,379	4
5	S25-4-UHL4	1	Carbide-tipped jointer	8	8	40	0,2	5	479	5,042	16
6	Z6-2	2	Carbide-tipped circular saw	1	6	30	0,2	15	350	0,458	2
7	SSF6-1	1	Carbide-tipped jointer	2	6	40	0,2	5	105	0,368	4
8	SR8-10	1	Carbide-tipped jointer	2	6	40	0,2	5	99	0,695	4
9	SFU-1	1	End milling cutter	1	3	4	0,06	20	196	1,225	3
10	FSSH-1A	1	Carbide-tipped rotary cutter	1	8	40	0,2	5	179	0,118	2
			End milling cutter	1	3	4	0,06	20	179	1,119	2
11	SVPG-1R	1	Morse-pattern twist bit	1	30	4	0,3	15	192	0,565	4
12	CVA-2	1	Morse-pattern twist bit	1	30	4	0,3	15	1009	2,968	4

Table A.2.15 Calculation of the area occupied by equipment

Model of machine	Number of machines	Area occupied by one machine, m^2	Required area, m^2
ZST-01	1	41	41
ZDK5-2	1	24,3	24,3
SF4-1A	1	12,2	12,2
SSF6-1	1	12,2	12,2
SR3-6	1	18,6	18,6
SR6-9	1	18,6	18,6
ZA-2A	1	18,0	18,0
S25-4-UHL4	1	27	27
KV2-3	1	14,3	14,3
VR-6	1	12,0	12,0
Z6-2	2	18,0	36,0
SR8-10	1	29,0	29,0
Section of turning	1	73,5	73,5
SFU-1	1	10,8	10,8
FSSH-1A	1	10,2	10,2
SVPG-1R	1	11,4	11,4
SVA-2	1	10,9	10,9
SHlPS-Kombi	1	15,2	15,2
SHlDB	1	8,5	8,5
Total			403,7

Table A.3.1 Calculation of energy requirements for machines

Equipment type	Model	Installed capacity, kW	Required capacity, kW	Annual time schedule of machine's work, machine-hour	Annual energy consumption, kWh
1	2	3	4	5	6
Crosscut saw	ZST-01	3	2,37	1856	4395,8
Ripsaw	ZDK5-2	34,5	27,24	865	23559,9
One-sided facer	SF4-1A	3,0	2,37	250	592,1
One-sided planer	SR3-6	5,5	4,34	144	625,3
Four-sided moulder	S25-4-UHL4	38,5	30,39	479	14559,1
Gluer	KV2-3	0,3	0,20	516,5	101,9
Clamping device	VR-6	2,2	1,74	172,2	299,0
One-sided facer	SSF6-1	5,5	4,34	105	455,7
One-sided planer	SR8-10	9,6	7,59	99,0	751,9
Disk saw with manual feeding	Z6-2	4,0	3,16	350	1106
Milling machine	SFU-1	3,20	2,53	196	495,2

Continuation of Table A.3.1

1	2	3	4	5	6
Milling machine with tenoning head	FSSH-1A	4,50	3,55	179	635,45
Drilling-grooving	SVPG-1R	2,2	1,74	192	334,1
Drilling-grooving with automatic feeding	CVA-2	2,2	1,74	1009	1755,7
Multi-purpose sanding machine	SHlPS-Kombi	3	2,37	1307	3098
Drum sanding machine	SHlDB	4,5	3,55	828	2939,4
Total	-	125,7	-	-	55704,6

Table A.3.2 Calculation of energy requirements for lighting

Energy sinks	Area, m^2	Power density, W/m^2	Calculated capacity, kW	Installed capacity, kW	Required capacity, kW	Number of burning hours, hours	Annual energy consumption, kWh
Industrial rooms	1500	20	30	39	34,9	630	21987
Administrative and domestic rooms	240,3	5	1,2	1,56	1,4	630	882
Total:	-	-	-	40,56	-	-	22869

Table A.4.1 Calculation of capital investments

Model/Type of equipment	Dismantled			Exploitable			Installed		
	Number, pieces	Unit cost, thousand rubles	Total cost, thousand rubbles	Number, pieces	Unit cost, thousand rubles	Total cost, thousand rubbles	Number, pieces	Unit cost, thousand rubles	Total cost, thousand rubbles
1	2	3	4	5	6	7	8	9	10
ZPA-40	1	8,85	8,85	-	-	-	-	-	-
SF6-2	1	30	30	-	-	-	-	-	-
SVPA-2	1	7,85	7,85	-	-	-	-	-	-
FS	1	18	18	-	-	-	-	-	-
SHlPS-5	1	25	25	-	-	-	-	-	-
SHlNSV	1	15	15	-	-	-	-	-	-
KV	1	2,7	2,7	-	-	-	-	-	-
ZDK-4	1	16,21	16,21	-	-	-	-	-	-

Continuation of Table A.4.1

1	2	3	4	5	6	7	8	9	10
Z6-2	1	10	10	2	10	20	-	-	-
Clamping device	1	5	5	-	-	-	-	-	-
Clamping device	1	5	5	-	-	-	-	-	-
Clamping device	1	5	5	-	-	-	-	-	-
ZST-01	-	-	-	-	-	-	1	63	63
ZDK5-2	-	-	-	1	62	62	-	-	-
SF4-1A	-	-	-	1	45	45	-	-	-
SR3-6	-	-	-	1	44	44	-	-	-
SR6-9	-	-	-	1	74	74	-	-	-
ZA-2A	-	-	-	1	55	55	-	-	-
S25-4-UHL4	-	-	-	1	180	180	-	-	-
SSF6-1	-	-	-	-	-	-	1	115	115
KV2-3	-	-	-	-	-	-	1	20	20
VR-6	-	-	-	-	-	-	1	22,35	22,35
SR8-10	-	-	-	-	-	-	1	500	500
FSSH-1A	-	-	-	1	40000	40000			
SFU-1	-	-	-	-	-	-	1	57,59	57,59
SVPG-1R	-	-	-	-	-	-	1	29,46	29,46
SVA-2	-	-	-	1	40600	40600	-	-	-
SHlDB	-	-	-	1	35000	35000	-	-	-
SHlPS-Kombi	-	-	-	-	-	-	1	49	49
Work table	-	-	-	-	-	-	2	2	4
Section of non-drive roller conveyer 2,0 m	-	-	-	-	-	-	52	2	104
Trolley non-drive with roller pivoting floor	-	-	-	-	-	-	5	2,3	11,5
Trolley non-drive with roller floor	-	-	-	-	-	-	2	2	4
Total:	-	-	148,61	-	-	595,6	-	-	979,9
Unaccounted-for equipment (10%)	10 %	-	14,861	10 %	-	59,56	-	-	-
Total:	-	-	163,471	-	-	655,16	-	-	979,9
Transport-storage expenses, installation and dismantling costs (10%)	10 %	-	16,347	10 %	-	65,516	25 %	-	244,975
Tools, accessories, inventory (3%)	3%	-	4,904	3%	-	19,65	3%	-	29,397
Total:	-	-	184,72 ±9,24	-	-	740,33 ±37,02	-	-	1254,27 ±62,71

Table A.4.2 Value calculations of main and auxiliary materials

Description of material	Units	Material consumption	Cost, thousand rubles	
			unit	for the program
Wane-edge softwood timber AUSS 8486-86	m^3	517	1200	620400
Plywood FU (10 mm)	m^3	46.51	6480	301385
Sandpaper	m^2	521.5	60	31290
PVA glue	kg	1369	36.3	49695
Furniture hinges	pieces	8400	0.5	4200
Furniture hinges	pieces	8400	0.4	3360
Eccentric	pieces	8400	1	8400
Screws	kg	255.3222	91.2	23285
Holders	pieces	159600	5	798000
Staples	pieces	478800	0.04	19152
Total	-	-	-	1859,167±92,958

Table A.4.3 Calculation of cost of water, hot water and electrical power

Type of expense	Units	Consumption	Cost, rubles	Total cost, thousand rubles
Electrical power	kWh	78573.6	1.304	102,460
Hot water	Giga cal	607.8	510	309,978
Water	m^3	1370.09	9.57	13,112
Total	-	-	-	425,550±21,278

Table A.4.4 Calculation of nominal working time of machines

Indices	Units	Plan for 2004
1. Number of calendar days	Days	366
Excluded days including	Days	115
a) Holidays	Days	11
б) Days off	Days	104
в) Shorten days	Hour	7
2. Operation time fund	Days	251
3. Shift system	Shifts	1
4. Number of machine-shift	Machine-shift	251
5. Nominal period of shift	Hour	8
6. Nominal number of machine-hour	Machine-hour	2008
7. Downtime during major repairs	Days	10
	Machine-hour	80
8. Fund of effective working time a year	Machine-shift	240
	Machine-hour	1913
9. Average period of shift	Hour	7,9

Table A.4.5 Calculation of working time of the worker for 2004

Indices	Values	Units
Calendar time fund	366	Days
Number of days off including:	115	Days
Holidays	11	Days
Days off	104	Days
Number of working days	251	Days
Absence from work including:	46	Days
Annual and extra leave	31,4	Days
Sick leave	12	Days
Training leave	1,4	Days
Other absence from work statute-permitted	0,6	Days
Absence from work permitted by the administration	0,6	Days
Number of effective working days	205	Days
Nominal period of working day	8	Hour
Downtime within a shift and downtimes in average a year	0,48	Hour
Average period of working time	7,52	Hour
Fund of effective work a year	1541,6	Hour

Table A.4.6 Salary accounting of main workers

Staff of workers	Class	Number of workers in a shift, persons	Number of working days, days	Required number of working days, person/day	Rate of tariff a day, rubles	Annual tariff fund, rubles
Sawyer	3	3	251	753	100	75300
Sawyer	4	3	251	753	120	90360
Joiner	4	3	251	753	120	90360
Joiner	3	2	251	502	100	50200
Machine-operator	4	3	251	753	120	90360
Machine-operator	3	3	251	753	100	75300
Grinder	4	2	251	502	120	60240
Marker	3	1	251	251	100	25100
Total	-	20±2	-	-	-	557220±55722

Table A.4.7 Salary accounting of auxiliary workers

Staff of workers	Number of workers in a shift, persons	Shift system, shifts	Number of working months a year, months	Class	Wage, rubles	Annual tariff fund, rubles
Adjuster	1	1	12	5	4000	48000
Repair man	1	1	12	5	3500	42000
Grinderman	1	1	12	5	4000	48000
Electrician	1	1	12	5	3500	42000
Total	4	-	-	-	-	180000

Table A.4.8 Salary accounting of technical staff

Post	Number, persons	Number of working months a year, months	Wage, rubles	Annual tariff fund, rubles
Shop superintendent	1	12	7000	84000
Shift foreman	1	12	5000	60000
Technologist	1	12	6000	72000
Head of technical control division	1	12	6000	72000
Office-cleaner	1	12	2000	24000
Total	5	-	-	312000

Table A.4.9 Annual salary accounting of staff

Staff	Number, persons	Annual tariff fund, thousand rubles	Bonus rate		Hour salary, thousand rubles	Regional bonus		Northern benefit		Main salary, thousand rubles	Additional salary		Annual salary accounting, thousand rubles
			%	thousand rubles		%	thousand rubles	%	thousand rubles		%	thousand rubles	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Main workers	20	557,220± 55,722	100	557,220± 55,722	1114,440± 111,444	20	222,888± 22,289	50	278,610± 27,861	1504,494± 150,449	16	240,719± 24,072	1745,213± 174,521
Auxiliary workers	4	180,000	100	180,000	360,000	20	72,000	50	90,000	486,000	16	77,760	563,760
Technical staff	5	312,000	100	312,000	624,000	20	124,800	50	156,000	842,400	-	-	842,400
Total	-	1049,220± 55,722	-	-	2098,440± 111,444	-	-	-	-	2832,894± 150,449	-	318,479± 24,072	3151,373± 174,521

Table A.4.10 Depreciation calculation

Kinds of basic assets	Depreciation rate, %	Cost of assets, thousand rubles	Amount of depreciation, thousand rubles
Building	1,2	666,792	8,0
Equipment	8,3	1635,06±81,753	135,71±6,786
Transport means	12,5	244,975±12,249	38,811±1,941
Tools	50	94,958±4,748	47,479±2,374
Total	-	2641,785±98,75	230±11,101

Table A.4.11 Maintenance and exploitation costs of equipment

Description of expenses	Sum, thousand rubles
Depreciation of equipment and transport means	230±11,101
Salary of auxiliary workers	563,760
Uniform social tax (35,6%)	200,7
Assessments to social insurance against accidents and occupational diseases (3,8%)	21,423
Assessments for services of a service shop (25%)	37,584
Costs of lubricating and cleaning materials (15%)	22,550
Current repairs (40%)	52,618
Major repairs (4,37%)	71,452±3,573
Total	1200,087±14,674

Table A.4.12 Machining workshop expenses

Description of expenses	Sum, thousand rubles
Salary of technical staff	842,4
Uniform social tax (35,6%)	300
Assessments to social insurance against accidents and occupational diseases (3,8%)	32,011
Depreciation of the building	8,0
Maintenance of the building (4%)	26,672
Current repairs (10%)	66,679
Major repairs (2,7%)	18
Assessments to protection of labour	14,4
Other assessments	19,2
Total	1327,362

Table A.4.14 Plan of sales outcome

Item name	Number of items, pieces	Shop costs, thousand rubles	Profitability, %	Financial income, thousand rubles
Double bed	2,000	7681,726±394,029	20 %	1536,345±78,806

Table A.4.15 Net profit calculation

Financial income, thousand rubles	Income tax, thousand rubles	Net profit, thousand rubles	Amount of depreciation, thousand rubles	Total profit, thousand rubles
1536,345±78,806	368,723±18,913	1167,622±59,893	230±11,101	1397,622±70,994

Table A.4.16 Price calculation

Item description	Conversion factor	Price, thousand rubles	Price of the item, thousand rubles
Double bed	1	8,000±0,5	8,000±0,5
Bed-side table	0.482	6,000±0,5	2,892±0,5
Chest of drawers with mirror	1.311	6,000±0,5	7,866±0,5
Folding wardrobe	1.816	6,000±0,5	10,896±0,5
Total	-	-	29,654±0,5

Table A.4.17 Economic indicators of capital investment efficiency

Indicator	2004					2005								
	August	September	October	November	December	January	February	March	April	May	June	July	August	September
Capital investments, rubles	1336133	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit, rubles	0	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469
CF	-1336133	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469	116469
CCF	-1336133	-1219664	-1103196	-986727	-870259	-753790	-637322	-520853	-404385	-287916	-171448	-54979	61489	177958
α_t	0,989	0,979	0,968	0,958	0,948	0,937	0,927	0,917	0,908	0,898	0,888	0,879	0,869	0,860
DCF	-1321813	113985	112764	111555	110360	109177	108007	106849	105704	104571	103451	102342	101245	100160
NPV	-1321813	-1207828	-1095064	-983509	-873149	-763972	-655965	-549116	-443411	-338840	-235389	-133047	-31802	68358

Table A.5.1. Properties of common pine and spruce

Specie	The quantity of growth layers in 1 cm	Latewood, %	Density, кg/m^3	Maximum moisture content in wood during water adsorption, %	Shrinkage, %		Swelling coefficient, % on % moisture			Modulus of rupture, N/mm^2	
					earlywood	latewood	radial	tangentional	volume	static bending strength	compression strength parallel to the grain
Common spruce	12,1	21	475	212	6,1	7,4	0,11	0,24	0,37	83,4	49,3
Common pine	11,8	26	546	185	6,7	7,5	0,15	0,27	0,44	95,1	53,0

Table A.5.2 Properties of PVA glue

Glue	Base	Viscosit yMPa*s eк. Brookfi eld HBT	Group of loading DIN EN 204	Point of whitenin g, ^{0}C	Value PH	Time in the open state of 150 g/m^2, minutes	Minimal time of pressing, s/min	Properties
Rako ll- E WB0 301	PVD	about 12.000	D3	about + 7	about 3	8...11	Gluing HPL/CPL: Coating: about 70 g/m^2 Pressing: +70 ^{0}C, about 40 seк.	single-component adhesive D3, quickly set under heating. High humidity and temperature resistance.

Table A.5.3 Moisture content of the panels

Glued-up panel	*m*, grams	m_0, grams	*MC*, %
Pine	28,72	26,65	7,21
Spruce	32,12	29,8	7,22
Pine and spruce	26,34	24,44	7,21

Table A.5.4 Measurement points

Measurement point		1st point	2nd point	3rd point	4th point	5th point
1st specimen observation №1 test №1						
Distance between points, mm		0	43	86,5	129,3	173,5
end 1	Bottom edge	0,4	0	0	0,05	0,4
	Thickness of the panel, mm	17,84	17,93	18,14	18,19	18,19
	Upper edge	18,24	17,93	18,14	18,24	18,59
Distance between points, mm		0	43	86,5	129,5	174,3
end 2	Bottom edge	0,4	0,08	0	0,08	0,3
	Thickness of the panel, mm	17,79	17,81	17,95	18	18,05
	Upper edge	18,19	17,89	17,95	18,08	18,35
Distance between points, mm		0	59	109	153	
longitudinal edge 1	Bottom edge	0,4	0,35	0,31	0,3	
	Thickness of the panel, mm	18,19	18,09	18,09	18,05	
	Upper edge	18,59	18,44	18,4	18,35	
Distance between points, mm		0	59	109	153	
longitudinal edge 2	Bottom edge	0,4	0,44	0,38	0,4	
	Thickness of the panel, mm	17,84	17,79	17,81	17,79	
	Upper edge	18,24	18,23	18,19	18,19	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
1st specimen observation №2 test №1						
Distance between points, mm		0	43	86,5	129,3	173,5
end 1	Bottom edge	0,04	0,15	0,35	0,35	0
	Thickness of the panel, mm	17,99	18,11	18,24	18,33	18,31
	Upper edge	18,03	18,26	18,59	18,68	18,31
Distance between points, mm		0	43	86,5	129,5	174,3
end 2	Bottom edge	0	0,15	0,35	0,4	0,06
	Thickness of the panel, mm	17,83	17,97	18,09	18,09	17,97
	Upper edge	17,83	18,12	18,44	18,49	18,03
Distance between points, mm		0	59	109	153	
longitudinal edge 1	Bottom edge	0	0,15	0,14	0,06	
	Thickness of the panel, mm	18,31	18,08	18,11	17,97	
	Upper edge	18,31	18,23	18,25	18,03	
Distance between points, mm		0	59	109	152,5	
longitudinal edge 2	Bottom edge	0,04	0,13	0,12	0	
	Thickness of the panel, mm	17,99	17,82	17,82	17,83	
	Upper edge	18,03	17,95	17,94	17,83	

Continuation of Table A.5.4

Measurement point		1st point	2nd point	3rd point	4th point	5th point
2nd specimen observation №1 test №1						
Distance between points, mm		0	43	87	130	175
end 1	Bottom edge	0	0,02	0,02	0	0
	Thickness of the panel, mm	18,15	18,15	18,1	18,04	17,89
	Upper edge	18,15	18,17	18,12	18,04	17,89
Distance between points, mm		0	42,5	87	129,5	174,5
end 2	Bottom edge	0	0,15	0,27	0,35	0,35
	Thickness of the panel, mm	18,14	18,03	17,95	17,79	17,68
	Upper edge	18,14	18,18	18,22	18,14	18,03
Distance between points, mm		0	58	108	152	
longitudinal edge 1	Bottom edge	0	0,12	0,28	0,35	
	Thickness of the panel, mm	17,89	17,84	17,77	17,68	
	Upper edge	17,89	17,96	18,05	18,03	
Distance between points, mm		0	58	108	152	
longitudinal edge 2	Bottom edge	0	0,01	0,01	0	
	Thickness of the panel, mm	18,15	18,14	18,11	18,14	
	Upper edge	18,15	18,15	18,12	18,14	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
2nd specimen observation №2 test №1						
Distance between points, mm		0	43	87	130	175
end 1	Bottom edge	0	0,58	0,87	0,54	0
	Thickness of the panel, mm	18,23	18,39	18,26	18,23	18,06
	Upper edge	18,23	18,97	19,13	18,77	18,06
Distance between points, mm		0	42,5	87	129,5	174,5
end 2	Bottom edge	0	0,63	1	0,84	0,35
	Thickness of the panel, mm	18,25	18,16	18,1	17,98	17,88
	Upper edge	18,25	18,79	19,1	18,82	18,23
Distance between points, mm		0	58	108	152	
longitudinal edge 1	Bottom edge	0	0,28	0,37	0,35	
	Thickness of the panel, mm	18,06	17,91	17,81	17,88	
	Upper edge	18,06	18,19	18,18	18,23	
Distance between points, mm		0	57	107	152	
longitudinal edge 2	Bottom edge	0	0,1	0,15	0	
	Thickness of the panel, mm	18,23	18,15	18,16	18,25	
	Upper edge	18,23	18,25	18,31	18,25	

Continuation of Table A.5.4

Measurement point		1st point	2nd point	3rd point	4th point	5th point
3rd specimen observation №1 test №1						
Distance between points, mm		0	42	86	128	172
end 1	Bottom edge	0,17	0	0	0,2	0,58
	Thickness of the panel, mm	17,81	17,97	18,08	18,09	18
	Upper edge	17,98	17,97	18,08	18,29	18,58
Distance between points, mm		0	42,5	87	130	174
end 2	Bottom edge	0,25	0,12	0	0,16	0,54
	Thickness of the panel, mm	17,69	17,85	17,93	17,9	17,9
	Upper edge	17,94	17,97	17,93	18,06	18,44
Distance between points, mm		0	58	108	152	
longitudinal edge 1	Bottom edge	0,58	0,55	0,52	0,54	
	Thickness of the panel, mm	18	18,02	18,07	17,9	
	Upper edge	18,58	18,57	18,59	18,44	
Distance between points, mm		0	58	108	152	
longitudinal edge 2	Bottom edge	0,17	0,36	0,35	0,25	
	Thickness of the panel, mm	17,81	17,71	17,74	17,69	
	Upper edge	17,98	18,07	18,09	17,94	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
3rd specimen observation №2 test №1						
Distance between points, mm		0	42	86	128	172
end 1	Bottom edge	0	0,3	0,3	0,37	0
	Thickness of the panel, mm	17,91	18,09	18,2	18,22	18,19
	Upper edge	17,91	18,39	18,5	18,59	18,19
Distance between points, mm		0	42,5	87	130	174
end 2	Bottom edge	0	0,31	0,3	0,35	0,08
	Thickness of the panel, mm	17,85	18,01	18,15	18,11	18,01
	Upper edge	17,85	18,32	18,45	18,46	18,09
Distance between points, mm		0	58	108	152	
longitudinal edge 1	Bottom edge	0	0,24	0,2	0,08	
	Thickness of the panel, mm	18,19	18,1	18,05	18,01	
	Upper edge	18,19	18,34	18,25	18,09	
Distance between points, mm		0	58	108	152	
longitudinal edge 2	Bottom edge	0	0,1	0,12	0	
	Thickness of the panel, mm	17,91	17,84	17,8	17,85	
	Upper edge	17,91	17,94	17,92	17,85	

Continuation of Table A.5.4

Measurement point		1st point	2nd point	3rd point	4th point	5th point
4th specimen observation №1 test №1						
Distance between points, mm		0	42,5	86	128,5	172
end 1	Bottom edge	0,37	0,09	0	0	0
	Thickness of the panel, mm	18,15	18,1	18,05	17,9	17,73
	Upper edge	18,52	18,19	18,05	17,9	17,73
Distance between points, mm		0	42,5	86	128,5	172
end 2	Bottom edge	0,24	0	0	0	0,25
	Thickness of the panel, mm	18,08	17,93	17,85	17,81	17,7
	Upper edge	18,32	17,93	17,85	17,81	17,95
Distance between points, mm		0	55	105	127	
longitudinal edge 1	Bottom edge	0	0,18	0,25	0,25	
	Thickness of the panel, mm	17,73	17,74	17,68	17,7	
	Upper edge	17,73	17,92	17,93	17,95	
Distance between points, mm		0	56	106	127	
longitudinal edge 2	Bottom edge	0,37	0,32	0,3	0,24	
	Thickness of the panel, mm	18,15	18,05	18,06	18,08	
	Upper edge	18,52	18,37	18,36	18,32	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
4th specimen observation №2 test №1						
Distance between points, mm		0	42,5	86	128,5	172
end 1	Bottom edge	0	0,23	0,34	0,15	0
	Thickness of the panel, mm	18,22	18,31	18,22	18,05	17,89
	Upper edge	18,22	18,54	18,56	18,2	17,89
Distance between points, mm		0	42,5	86	128,5	172
end 2	Bottom edge	0	0,23	0,42	0,4	0,36
	Thickness of the panel, mm	18,22	18,12	18,2	18	17,85
	Upper edge	18,22	18,35	18,62	18,4	18,21
Distance between points, mm		0	55	105	127	
longitudinal edge 1	Bottom edge	0	0,25	0,36	0,36	
	Thickness of the panel, mm	17,89	17,83	17,79	17,85	
	Upper edge	17,89	18,08	18,15	18,21	
Distance between points, mm		0	56	106	127	
longitudinal edge 2	Bottom edge	0	0,08	0	0	
	Thickness of the panel, mm	18,22	18,16	18,19	18,22	
	Upper edge	18,22	18,24	18,19	18,22	

Continuation of Table A.5.4

Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from spruce observation №1 test №1						
Distance between points, mm		0	45	89	133	178
end 1	Bottom edge	0,38	0,32	0,2	0	0
	Thickness of the panel, mm	17,9	18,01	18,09	18,15	17,96
	Upper edge	18,28	18,33	18,29	18,15	17,96
Distance between points, mm		0	44,5	89	134	178
end 2	Bottom edge	0	0	0	0,02	0,15
	Thickness of the panel, mm	17,63	17,77	17,92	17,96	17,93
	Upper edge	17,63	17,77	17,92	17,98	18,08
Distance between points, mm		0	58	108	128	
longitudinal edge 1	Bottom edge	0	0	0,15	0,15	
	Thickness of the panel, mm	17,96	18,03	18	17,93	
	Upper edge	17,96	18,03	18,15	18,08	
Distance between points, mm		0	58	108	128	
longitudinal edge 2	Bottom edge	0,38	0,27	0,15	0	
	Thickness of the panel, mm	17,9	17,78	17,73	17,63	
	Upper edge	18,28	18,05	17,88	17,63	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from spruce observation №2 test №1						
Distance between points, mm		0	45	89	133	178
end 1	Bottom edge	0,23	0,2	0,2	0,1	0
	Thickness of the panel, mm	18	18,27	18,27	18,35	18,21
	Upper edge	18,23	18,47	18,47	18,45	18,21
Distance between points, mm		0	44,5	89	134	178
end 2	Bottom edge	0	0,15	0,44	0,44	0,55
	Thickness of the panel, mm	17,8	18,01	18,05	18,15	18,05
	Upper edge	17,8	18,16	18,49	18,59	18,6
Distance between points, mm		0	58	108	128	
longitudinal edge 1	Bottom edge	0	0,35	0,45	0,55	
	Thickness of the panel, mm	18,21	18,06	18,03	18,05	
	Upper edge	18,21	18,41	18,48	18,6	
Distance between points, mm		0	58	108	128	
longitudinal edge 2	Bottom edge	0,23	0,22	0,06	0	
	Thickness of the panel, mm	18	17,9	17,85	17,8	
	Upper edge	18,23	18,12	17,91	17,8	

Continuation of Table A.5.4

Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from pine observation №1 test №1						
Distance between points, mm		0	42,3	84,6	127,1	169,8
end 1	Bottom edge	0	0,11	0,16	0	0
	Thickness of the panel, mm	18,05	18,09	17,92	18	17,83
	Upper edge	18,05	18,2	18,08	18	17,83
Distance between points, mm		0	43	85	128	171
end 2	Bottom edge	0	0	0,27	0,11	0
	Thickness of the panel, mm	18	18,03	17,9	17,87	17,72
	Upper edge	18	18,03	18,17	17,98	17,72
Distance between points, mm		0	60	110	128	
longitudinal edge 1	Bottom edge	0	0	0,04	0	
	Thickness of the panel, mm	17,83	17,81	17,75	17,72	
	Upper edge	17,83	17,81	17,79	17,72	
Distance between points, mm		0	59	109	128	
longitudinal edge 2	Bottom edge	0	0	0	0	
	Thickness of the panel, mm	18,05	18,11	18,09	18	
	Upper edge	18,05	18,11	18,09	18	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from pine observation №2 test №1						
Distance between points, mm		0	42,3	84,6	127,1	169,8
end 1	Bottom edge	0,2	0,19	0	0,03	0,16
	Thickness of the panel, mm	18,13	18,2	18,13	18,08	17,97
	Upper edge	18,33	18,39	18,13	18,11	18,13
Distance between points, mm		0	43	85	128	171
end 2	Bottom edge	0,13	0,15	0	0,03	0,17
	Thickness of the panel, mm	18,15	18,12	18,05	17,98	17,78
	Upper edge	18,28	18,27	18,05	18,01	17,95
Distance between points, mm		0	60	110	128	
longitudinal edge 1	Bottom edge	0,16	0,27	0,27	0,17	
	Thickness of the panel, mm	17,97	17,87	17,9	17,78	
	Upper edge	18,13	18,14	18,17	17,95	
Distance between points, mm		0	59	109	128	
longitudinal edge 2	Bottom edge	0,2	0,37	0,32	0,13	
	Thickness of the panel, mm	18,13	18,1	18,15	18,15	
	Upper edge	18,33	18,47	18,47	18,28	

Table A.5.5 Measurement points

Measurement point		1st point	2nd point	3rd point	4th point	5th point
1st specimen observation №1 test №2						
Distance between points, mm		0	44	86,5	130	172,5
end 1	Bottom edge	0,37	0,12	0	0,1	0,55
	Thickness of the panel, mm	18,12	18,19	18,17	18	17,88
	Upper edge	18,49	18,31	18,17	18,1	18,43
Distance between points, mm		0	44,5	87	130	172,5
end 2	Bottom edge	0,25	0	0	0	0,27
	Thickness of the panel, mm	18,15	18,15	18,06	17,92	17,88
	Upper edge	18,4	18,15	18,06	17,92	18,15
Distance between points, mm		0	50	100	152	
longitudinal edge 1	Bottom edge	0,55	0,52	0,42	0,27	
	Thickness of the panel, mm	17,88	17,86	17,87	17,88	
	Upper edge	18,43	18,38	18,29	18,15	
Distance between points, mm		0	50	100	152	
longitudinal edge 2	Bottom edge	0,37	0,27	0,3	0,25	
	Thickness of the panel, mm	18,12	18,22	18,19	18,15	
	Upper edge	18,49	18,49	18,49	18,4	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
1st specimen observation №2 test №2						
Distance between points, mm		0	44	86,5	130	172,5
end 1	Bottom edge	0,22	0,08	0	0,2	0,8
	Thickness of the panel, mm	18,15	18,16	18,18	18,07	17,85
	Upper edge	18,37	18,24	18,18	18,27	18,65
Distance between points, mm		0	44,5	87	130	172,5
end 2	Bottom edge	0,2	0,03	0	0,13	0,58
	Thickness of the panel, mm	18,12	18,17	18,14	18,05	17,88
	Upper edge	18,32	18,2	18,14	18,18	18,46
Distance between points, mm		0	50	100	152	
longitudinal edge 1	Bottom edge	0,8	0,9	0,85	0,58	
	Thickness of the panel, mm	17,85	17,81	17,82	17,88	
	Upper edge	18,65	18,71	18,67	18,46	
Distance between points, mm		0	50	100	152	
longitudinal edge 2	Bottom edge	0,22	0,37	0,37	0,2	
	Thickness of the panel, mm	18,15	18,12	18,12	18,12	
	Upper edge	18,37	18,49	18,49	18,32	

Continuation of Table A.5.5

Measurement point		1st point	2nd point	3rd point	4th point	5th point
2nd specimen observation №1 test №2						
Distance between points, mm		0	44	86,5	130,5	173,5
end 1	Bottom edge	0	0,13	0,13	0,05	0
	Thickness of the panel, mm	17,75	18	18,17	18,32	18,23
	Upper edge	17,75	18,13	18,3	18,37	18,23
Distance between points, mm		0	42,5	86,5	129,5	174
end 2	Bottom edge	0	0,15	0,25	0,13	0
	Thickness of the panel, mm	17,81	17,94	18,01	18,12	18,17
	Upper edge	17,81	18,09	18,26	18,25	18,17
Distance between points, mm		0	50	100	151	
longitudinal edge 1	Bottom edge	0	0,08	0,08	0	
	Thickness of the panel, mm	18,23	18,15	18,19	18,17	
	Upper edge	18,23	18,23	18,27	18,17	
Distance between points, mm		0	50	100	152	
longitudinal edge 2	Bottom edge	0	0,05	0,07	0	
	Thickness of the panel, mm	17,75	17,81	17,81	17,81	
	Upper edge	17,75	17,86	17,88	17,81	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
2nd specimen observation №2 test №2						
Distance between points, mm		0	44,7	87	131	173,7
end 1	Bottom edge	0	0,25	0,26	0	0,1
	Thickness of the panel, mm	17,79	18,09	18,23	18,41	18,24
	Upper edge	17,79	18,34	18,49	18,41	18,34
Distance between points, mm		0	42,5	86,5	129,5	174
end 2	Bottom edge	0	0,22	0,38	0,11	0,16
	Thickness of the panel, mm	17,85	18,1	18,16	18,34	18,25
	Upper edge	17,85	18,32	18,54	18,45	18,41
Distance between points, mm		0	50	100	151	
longitudinal edge 1	Bottom edge	0,1	0,28	0,32	0,16	
	Thickness of the panel, mm	18,24	18,17	18,16	18,25	
	Upper edge	18,34	18,45	18,48	18,41	
Distance between points, mm		0	50	100	152	
longitudinal edge 2	Bottom edge	0	0,18	0,17	0	
	Thickness of the panel, mm	17,79	17,8	17,8	17,85	
	Upper edge	17,79	17,98	17,97	17,85	

Continuation of Table A.5.5

Measurement point		1st point	2nd point	3rd point	4th point	5th point
3rd specimen observation №1 test №2						
Distance between points, mm		0	44	86	130,5	173
end 1	Bottom edge	0,21	0	0	0,23	0,46
	Thickness of the panel, mm	18,2	18,24	18,18	18,07	17,98
	Upper edge	18,41	18,24	18,18	18,3	18,44
Distance between points, mm		0	44	86,5	130,5	172,5
end 2	Bottom edge	0,3	0,1	0	0	0,27
	Thickness of the panel, mm	18,18	18,1	18,05	17,95	17,35
	Upper edge	18,48	18,2	18,05	17,95	17,62
Distance between points, mm		0	50	100	152	
longitudinal edge 1	Bottom edge	0,46	0,45	0,37	0,27	
	Thickness of the panel, mm	17,98	17,93	17,9	17,35	
	Upper edge	18,44	18,38	18,27	17,62	
Distance between points, mm		0	50	100	152,5	
longitudinal edge 2	Bottom edge	0,21	0,26	0,33	0,3	
	Thickness of the panel, mm	18,2	18,21	18,15	18,18	
	Upper edge	18,41	18,47	18,48	18,48	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
3rd specimen observation №2 test №2						
Distance between points, mm		0	44	86	130,5	173
end 1	Bottom edge	0,24	0,11	0	0,39	0,65
	Thickness of the panel, mm	18,3	18,27	18,26	18,14	18
	Upper edge	18,54	18,38	18,26	18,53	18,65
Distance between points, mm		0	44	86,5	130,5	172,5
end 2	Bottom edge	0,27	0,15	0	0,21	0,53
	Thickness of the panel, mm	18,21	18,14	18,13	18,01	17,85
	Upper edge	18,48	18,29	18,13	18,22	18,38
Distance between points, mm		0	50	100	152	
longitudinal edge 1	Bottom edge	0,65	0,58	0,58	0,53	
	Thickness of the panel, mm	18	17,91	17,91	17,85	
	Upper edge	18,65	18,49	18,49	18,38	
Distance between points, mm		0	50	100	152,5	
longitudinal edge 2	Bottom edge	0,24	0,33	0,33	0,27	
	Thickness of the panel, mm	18,3	18,22	18,18	18,21	
	Upper edge	18,54	18,55	18,51	18,48	

Continuation of Table A.5.5

Measurement point		1st point	2nd point	3rd point	4th point	5th point
4th specimen observation №1 test №2						
Distance between points, mm		0	43	86	129,8	172,6
end 1	Bottom edge	0,09	0	0,07	0,13	0,3
	Thickness of the panel, mm	17,91	18,08	18,1	18,25	18,3
	Upper edge	18	18,08	18,17	18,38	18,6
Distance between points, mm		0	43	85,9	128,9	171,4
end 2	Bottom edge	0,26	0,2	0,14	0	0,14
	Thickness of the panel, mm	17,81	17,97	17,97	18,11	18,19
	Upper edge	18,07	18,17	18,11	18,11	18,33
Distance between points, mm		0	50	100	152	
longitudinal edge 1	Bottom edge	0,3	0,36	0,26	0,14	
	Thickness of the panel, mm	18,3	18,23	18,23	18,19	
	Upper edge	18,6	18,59	18,49	18,33	
Distance between points, mm		0	50	100	151	
longitudinal edge 2	Bottom edge	0,09	0,24	0,28	0,26	
	Thickness of the panel, mm	17,91	17,88	17,83	17,81	
	Upper edge	18	18,12	18,11	18,07	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
4th specimen observation №2 test №2						
Distance between points, mm		0	43	86	129,8	172,6
end 1	Bottom edge	0,2	0	0,1	0,1	0,15
	Thickness of the panel, mm	17,95	18,13	18,27	18,31	18,31
	Upper edge	18,15	18,13	18,37	18,41	18,46
Distance between points, mm		0	43	85,9	128,9	171,4
end 2	Bottom edge	0,33	0,25	0,2	0	0
	Thickness of the panel, mm	17,75	17,94	18,03	18,15	18,2
	Upper edge	18,08	18,19	18,23	18,15	18,2
Distance between points, mm		0	50	100	152	
longitudinal edge 1	Bottom edge	0,15	0,27	0,19	0	
	Thickness of the panel, mm	18,31	18,23	18,19	18,2	
	Upper edge	18,46	18,5	18,38	18,2	
Distance between points, mm		0	50	100	151	
longitudinal edge 2	Bottom edge	0,2	0,22	0,32	0,33	
	Thickness of the panel, mm	17,95	17,83	18,78	17,75	
	Upper edge	18,15	18,05	19,1	18,08	

Continuation of Table A.5.5

Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from spruce observation №1 test №2						
Distance between points, mm		0	44	88	132	176
end 1	Bottom edge	0	0	0,12	0,09	0
	Thickness of the panel, mm	18,36	18,39	18,27	18,12	18
	Upper edge	18,36	18,39	18,39	18,21	18
Distance between points, mm		0	44	88	132	176
end 2	Bottom edge	0	0	0,09	0,12	0
	Thickness of the panel, mm	18,08	18,12	18,1	17,97	17,86
	Upper edge	18,08	18,12	18,19	18,09	17,86
Distance between points, mm		0	50	100	150,8	
longitudinal edge 1	Bottom edge	0	0	0	0	
	Thickness of the panel, mm	18	17,87	17,88	17,86	
	Upper edge	18	17,87	17,88	17,86	
Distance between points, mm		0	50	100	151,5	
longitudinal edge 2	Bottom edge	0	0,09	0,08	0	
	Thickness of the panel, mm	18,36	18,18	18,15	18,08	
	Upper edge	18,36	18,27	18,23	18,08	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from spruce observation №2 test №2						
Distance between points, mm		0	44,5	89	133,5	178
end 1	Bottom edge	0	0,03	0,14	0,03	0
	Thickness of the panel, mm	18,36	18	18,36	18,3	18,03
	Upper edge	18,36	18,03	18,5	18,33	18,03
Distance between points, mm		0	44,5	89	133,5	178
end 2	Bottom edge	0	0	0,1	0,1	0,06
	Thickness of the panel, mm	18,18	18,29	18,18	18,1	17,9
	Upper edge	18,18	18,29	18,28	18,2	17,96
Distance between points, mm		0	50	100	151	
longitudinal edge 1	Bottom edge	0	0,09	0,1	0,06	
	Thickness of the panel, mm	18,03	17,86	17,83	17,9	
	Upper edge	18,03	17,95	17,93	17,96	
Distance between points, mm		0	50	100	151,5	
longitudinal edge 2	Bottom edge	0	0,15	0,13	0	
	Thickness of the panel, mm	18,36	18,2	18,1	18,18	
	Upper edge	18,36	18,35	18,23	18,18	

Continuation of Table A.5.5

Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from pine observation №1 test №2						
Distance between points, mm		0	42,5	85,5	127,5	170
end 1	Bottom edge	0,07	0	0,12	0,03	0
	Thickness of the panel, mm	18,13	18,28	18,27	18,38	18,36
	Upper edge	18,2	18,28	18,39	18,41	18,36
Distance between points, mm		0	42,5	85,5	127,5	170
end 2	Bottom edge	0	0,07	0,26	0,12	0,07
	Thickness of the panel, mm	17,88	18,06	18,11	18,16	18,25
	Upper edge	17,88	18,13	18,37	18,28	18,32
Distance between points, mm		0	50	100	151,5	
longitudinal edge 1	Bottom edge	0	0	0	0,07	
	Thickness of the panel, mm	18,36	18,31	18,26	18,25	
	Upper edge	18,36	18,31	18,26	18,32	
Distance between points, mm		0	50	100	152	
longitudinal edge 2	Bottom edge	0,07	0,14	0,07	0	
	Thickness of the panel, mm	18,13	17,99	17,97	17,88	
	Upper edge	18,2	18,13	18,04	17,88	
Measurement point		1st point	2nd point	3rd point	4th point	5th point
Specimen from pine observation №2 test №2						
Distance between points, mm		0	42,5	85,5	127,5	170
end 1	Bottom edge	0,12	0	0,03	0,03	0
	Thickness of the panel, mm	18,08	18,3	18,35	18,39	18,37
	Upper edge	18,2	18,3	18,38	18,42	18,37
Distance between points, mm		0	42,5	85,5	127,5	170
end 2	Bottom edge	0	0,12	0,22	0,15	0
	Thickness of the panel, mm	17,9	18,1	18,17	18,24	18,15
	Upper edge	17,9	18,22	18,39	18,39	18,15
Distance between points, mm		0	50	100	151,5	
longitudinal edge 1	Bottom edge	0	0,06	0,08	0	
	Thickness of the panel, mm	18,37	18,27	18,27	18,15	
	Upper edge	18,37	18,33	18,35	18,15	
Distance between points, mm		0	50	100	152	
longitudinal edge 2	Bottom edge	0,12	0,15	0,14	0	
	Thickness of the panel, mm	18,08	17,96	17,92	17,9	
	Upper edge	18,2	18,11	18,06	17,9	

Appendix B

B.1.5 Questionnaire

The survey is conducted by the Furniture and Design Department of the Arkhangelsk State Technical University.

The aim of the survey is to determine the basic characteristics of furniture that meets consumers' demands.

Please, answer the questions carefully so that we will be able to take your wishes into account when developing new furniture models.

1. What kind of furniture would you like to buy in the near future?

A set of bedroom furniture	
A set of living room furniture	
A set of children room furniture	
Furniture for the hallway	
A set of kitchen furniture	
Your variant	

1. What material would you prefer your furniture to be made of?

Solid wood	
Particleboard	
Plywood	
MDF	
Other materials	
It doesn't matter	

2. What furniture style do you prefer?

Classical "Royal"	
Contemporary	

3. What species of wood do you prefer, in terms of colour and texture?

Pine	
Oak	
Cherry	
Your variant	

4. What is more important for you in the furniture you purchase? Estimate using a 5-point system, where 5 is the highest and 1 is the lowest point:

Properties	1	2	3	4	5
Ecological safety					
Quality					
Colour					
Design					
Area occupied by furniture					
Manufacturing firm					
Price					

5. After what period of time would you like to change your furniture? ______years.

6. How much are you prepared to spend on furniture?

Less than 15,000 rubles	
From 15,000 to 20,000 rubles	
From 20,000 to 25,000 rubles	
From 25,000 to 30,000 rubles	
More than 30,000 rubles	

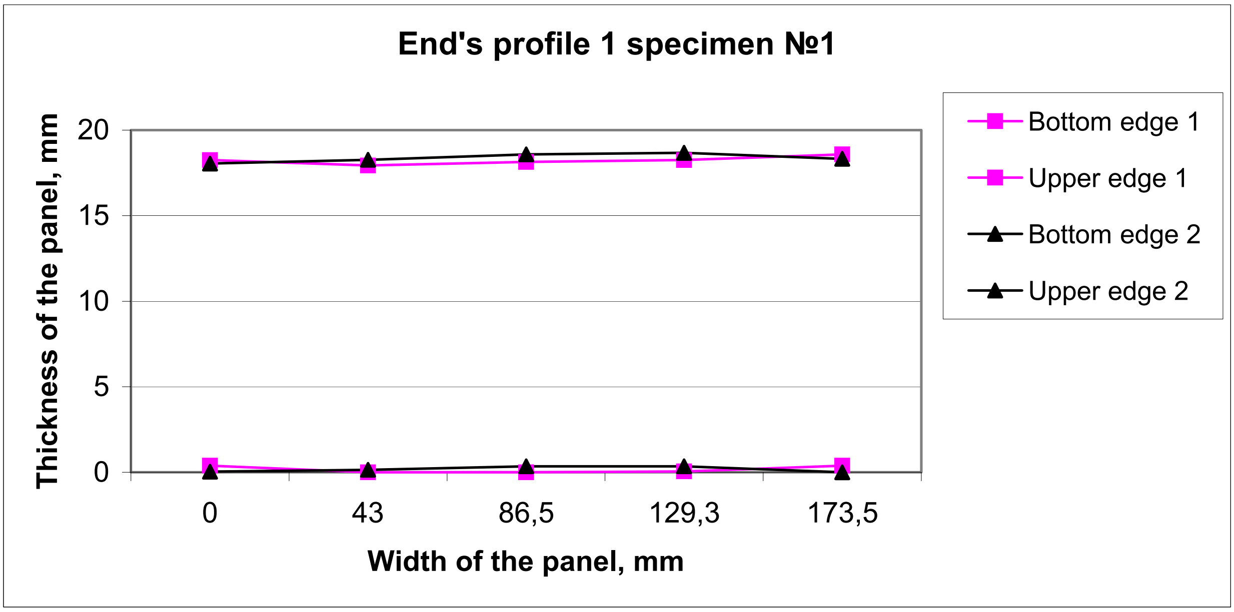
7. Your age:

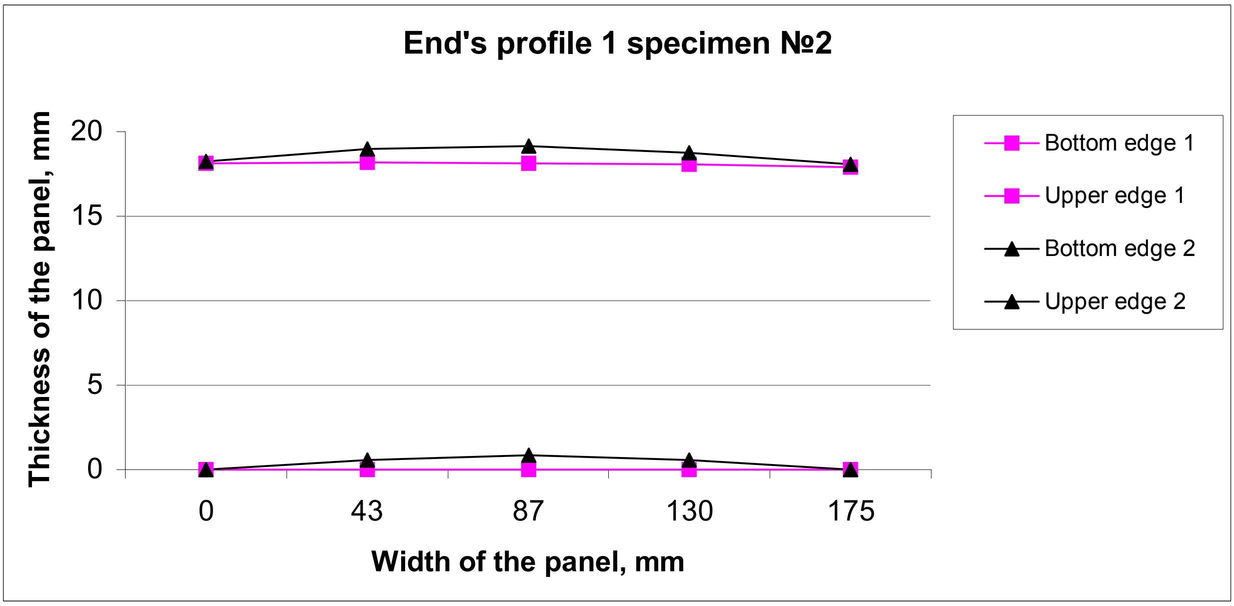
25 or under	
25 to 55	
Over 55	

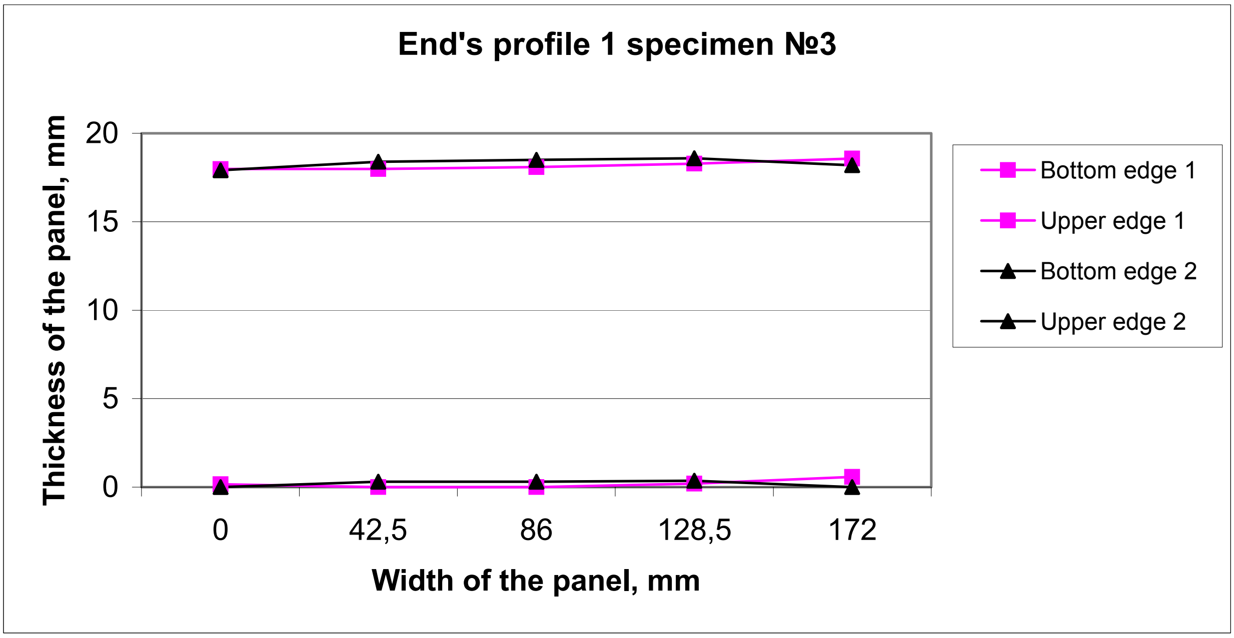
8. Monthly income of your household:

Less than 5,000 rubles	
From 5,000 to 8,000 rubles	
From 8,000 to 15,000 rubles	
More than 15,000 rubles	

We thank you for completing this questionnaire.


End's profile 1 specimen №1
Thickness of the panel, mm
20
15
10
5
0
0
43
86,5
129,3
173,5
Width of the panel, mm
Bottom edge 1
Upper edge 1
Bottom edge 2
Upper edge 2


End's profile 1 specimen №2
Thickness of the panel, mm
20
15
10
5
0
0
43
87
130
175
Width of the panel, mm
Bottom edge 1
Upper edge 1
Bottom edge 2
Upper edge 2



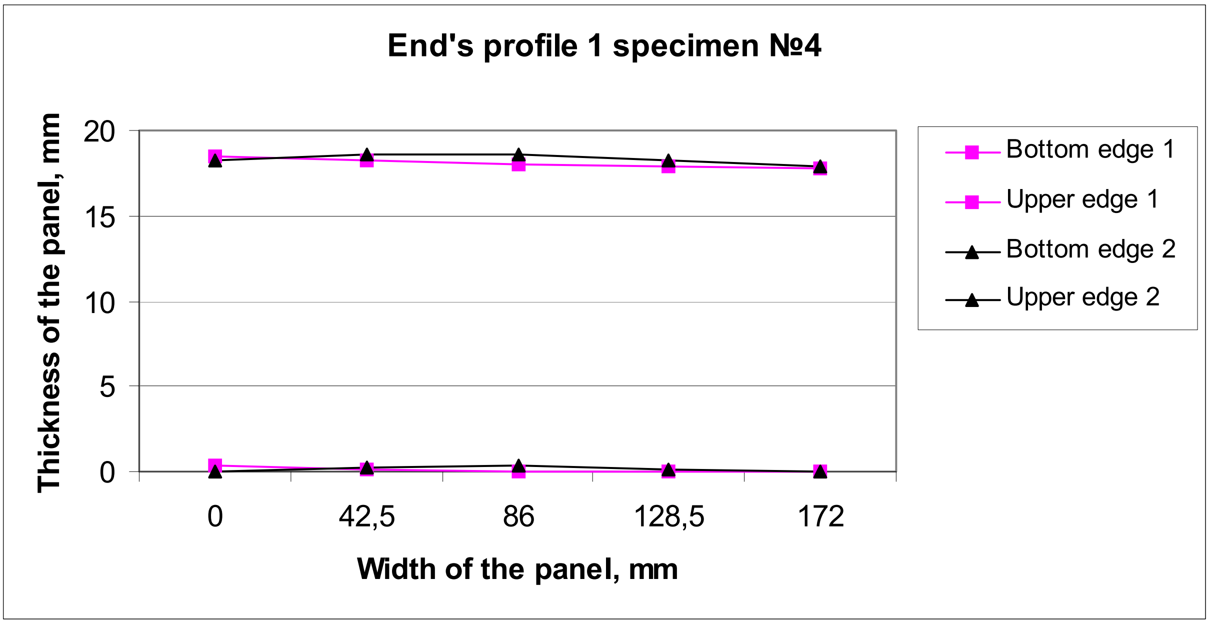
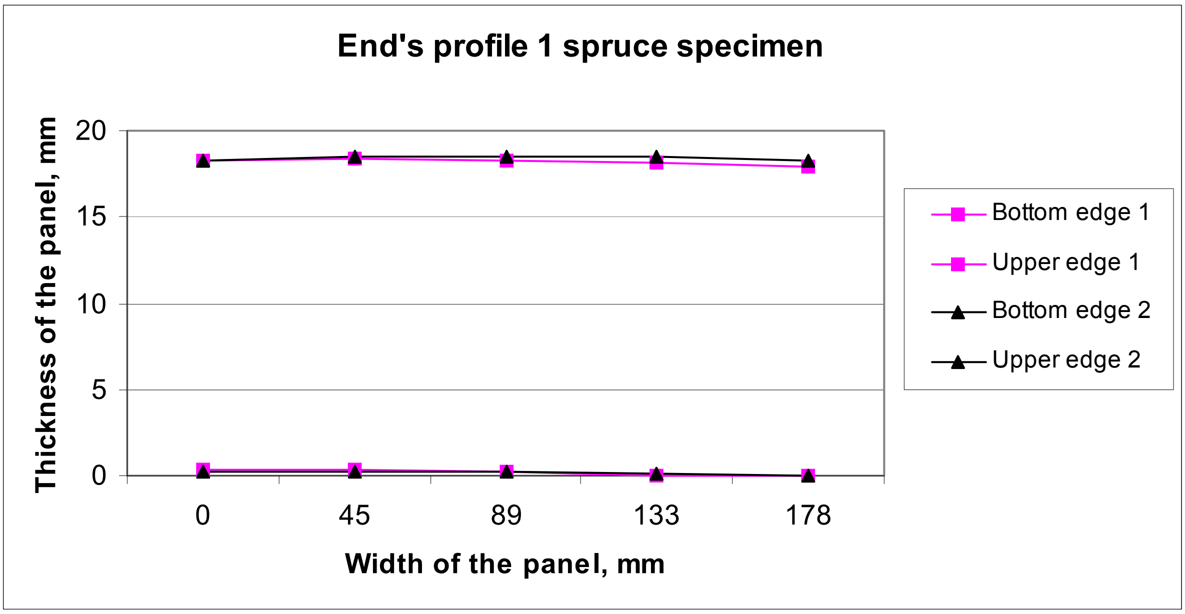


Figure B.5.1 Ends' profiles of the combine glued-up panels

Comment: Factor C_1 effects on the bottom and upper edges 1, C_2 – on the bottom and upper edges 2 accordingly.



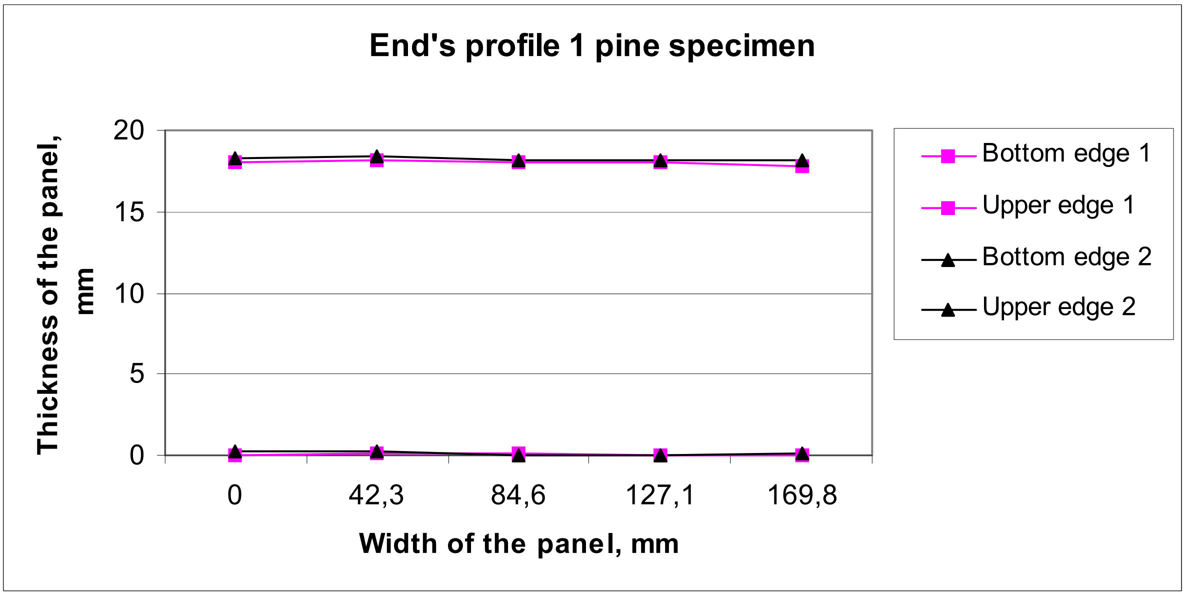
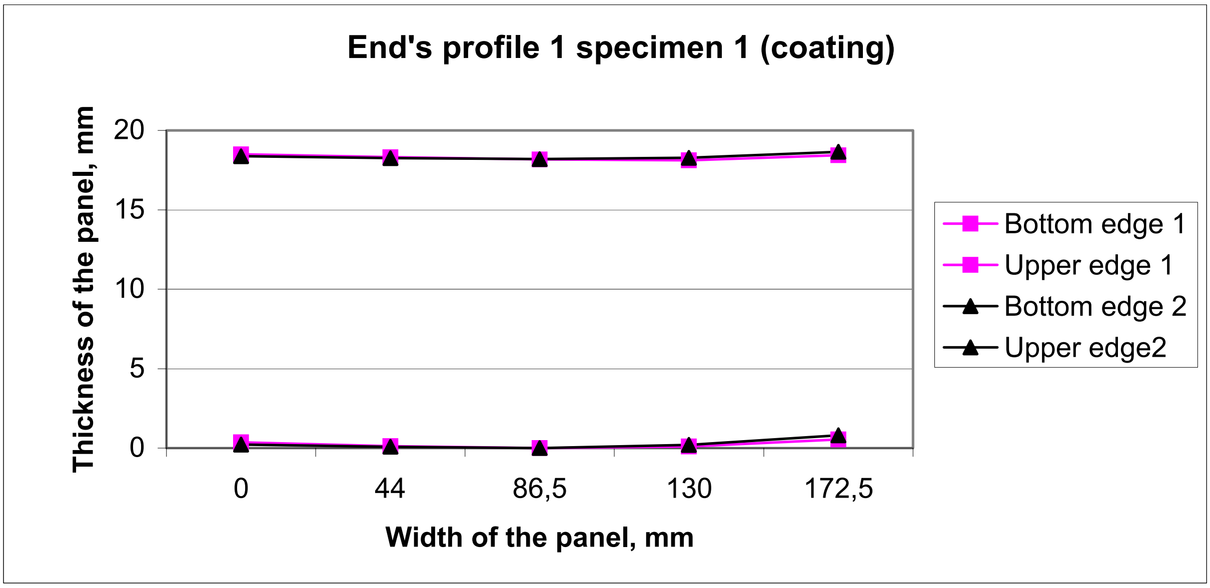
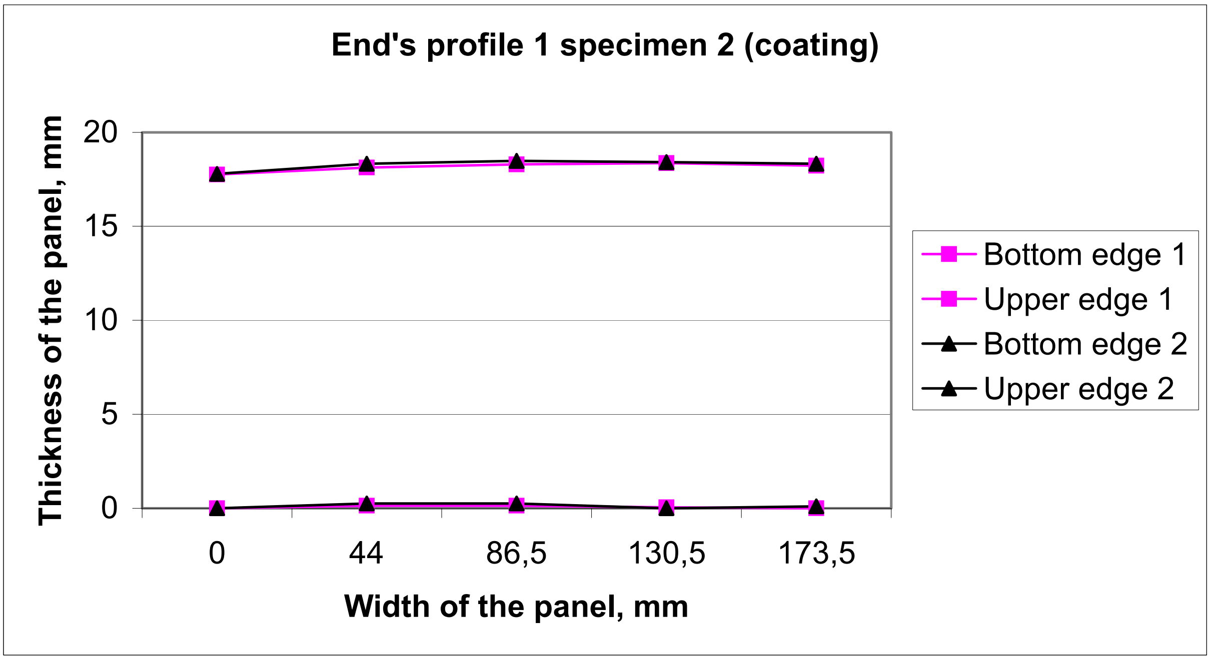
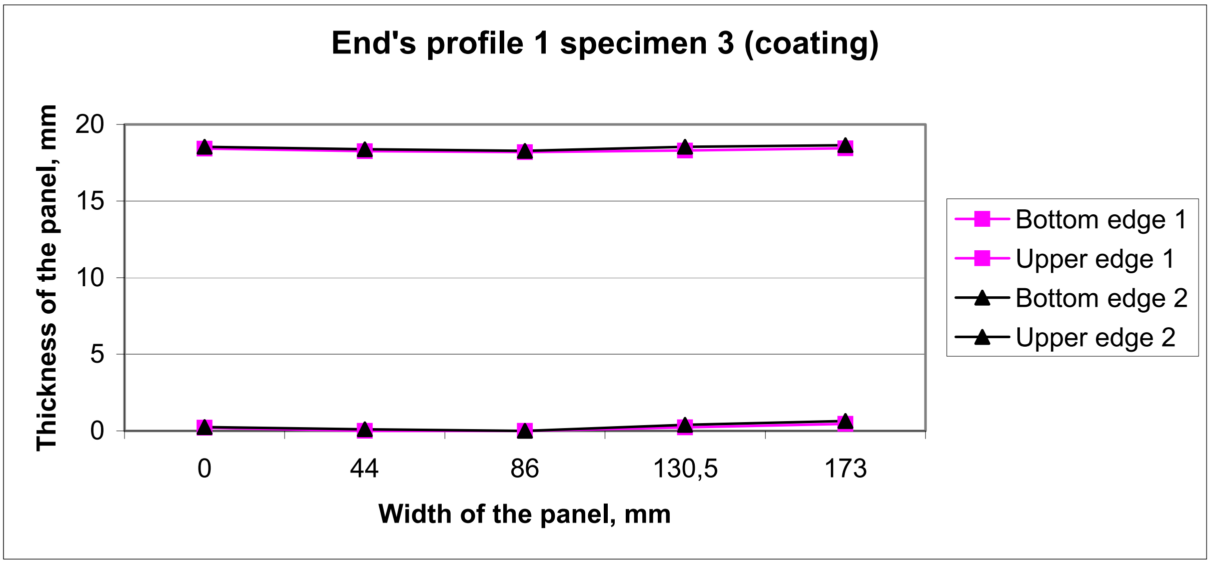


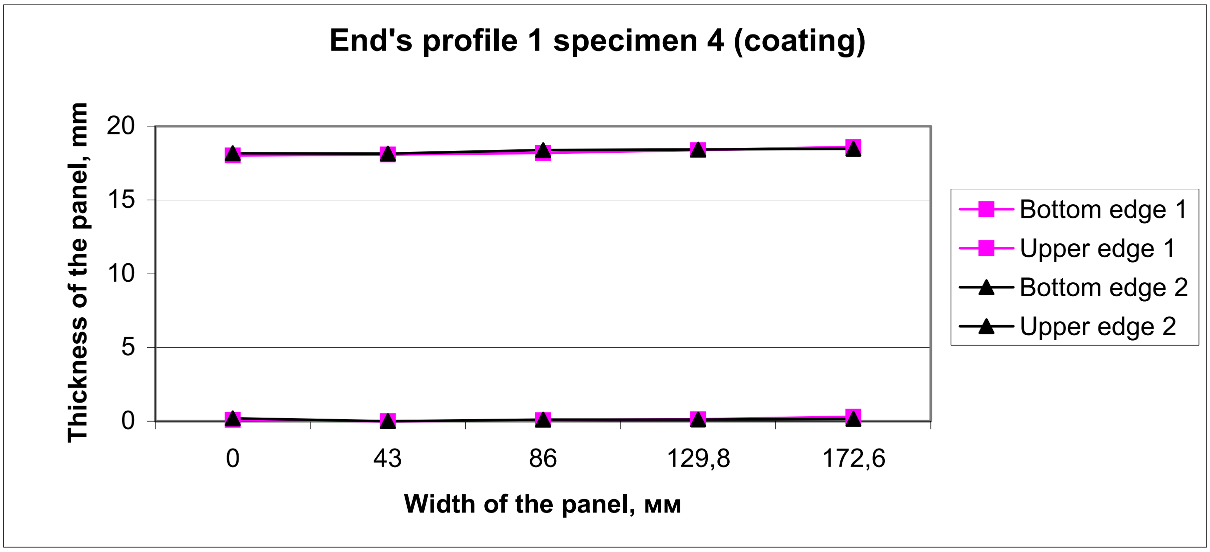
Figure B.5.2 Ends' profiles of the panels from pine and spruce

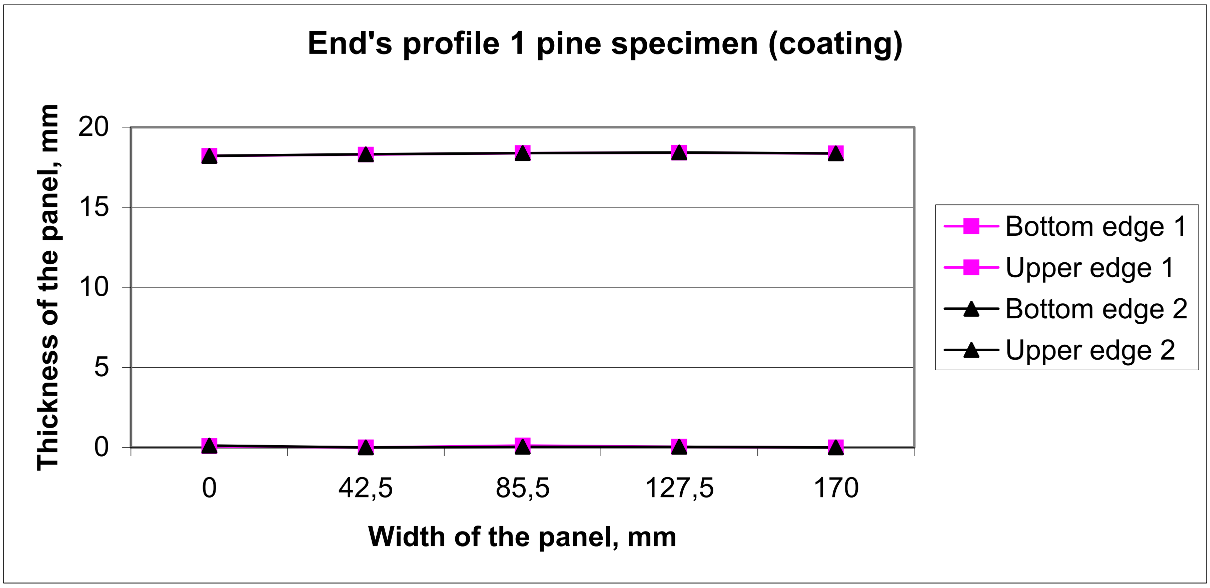
Comment: Factor C_1 effects on the bottom and upper edges 1, C_2 – on the bottom and upper edges 2 accordingly.


End's profile 1 specimen 1 (coating)
Thickness of the panel, mm
20
15
10
5
0
0
44
86,5
130
172,5
Width of the panel, mm
Bottom edge 1
Upper edge 1
Bottom edge 2
Upper edge2


End's profile 1 specimen 2 (coating)
Thickness of the panel, mm
20
15
10
5
0
0
44
86,5
130,5
173,5
Width of the panel, mm
Bottom edge 1
Upper edge 1
Bottom edge 2
Upper edge 2


End's profile 1 specimen 3 (coating)
Thickness of the panel, mm
20
15
10
5
0
0
44
86
130,5
173
Width of the panel, mm
Bottom edge 1
Upper edge 1
Bottom edge 2
Upper edge 2





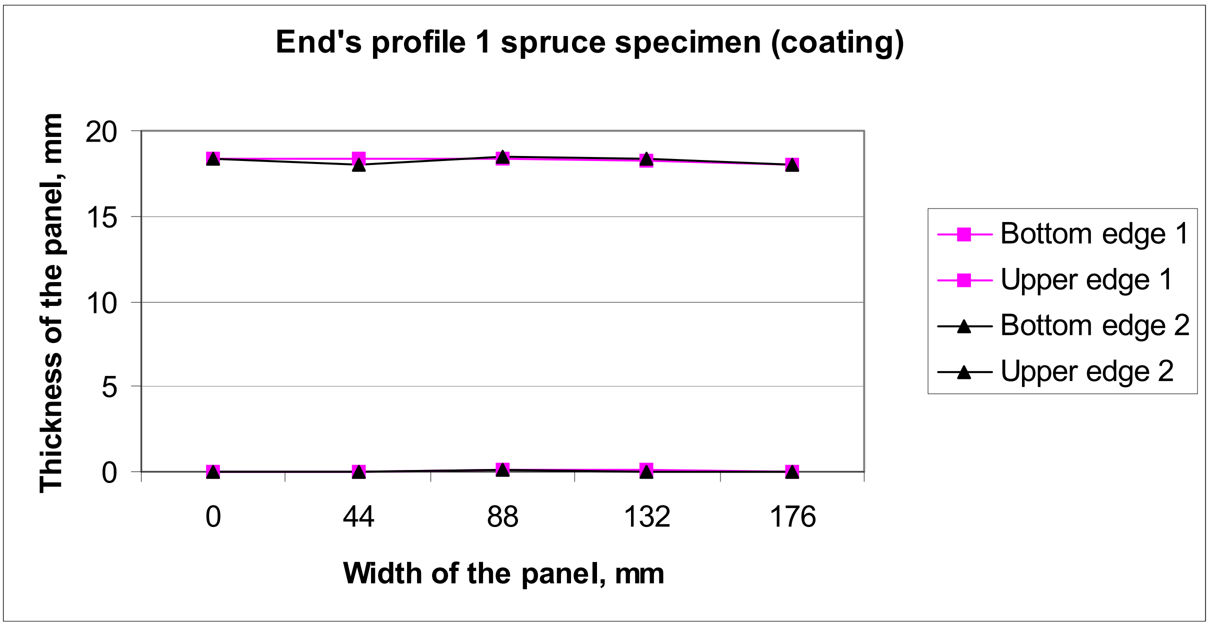


Figure B.5.3 Ends' profiles of the coated panels

Comment: Factor C_1 effects on the bottom and upper edges 1, C_2 – on the bottom and upper edges 2 accordingly.