Waste Minimization in the Furniture Industry

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Abstract: *The objective of the paper is to identify the determinants of service quality as well as its impact on the satisfaction of public transport commuters. The paper explores the relationship between service quality and customer satisfaction in a public transport service taking into account both internal and external perspectives. In order to analyse this relationship, the concepts of service quality, consumer satisfaction and dissatisfaction are assessed. A model of analysis is developed aiming at explaining this relationship and guiding the empirical study. This is based on an exploratory case study of a metro company in Europe. The results of the study put in evidence two key findings. The first is related to the level of service quality in its main dimensions. We conclude that reliability, security, speed, comfort and punctuality are quality dimensions of greater importance for the public transport services. Secondly, the study explores satisfaction and their determinants. Despite literature stipulates the existence of a distinction between the constructs of quality and satisfaction, this study found that the transport company, non-customers and customers clearly do not make such a distinction.*

Keywords: *service quality, satisfaction, dissatisfaction, public transport*

1. INTRODUCTION

There is a lot of energetic and economic reasons, as well as environmental reasons, why every furniture manufacturing company would have to consider the possibilities for the reduction of waste generated during the furniture manufacturing. The waste minimization in some of these companies contributes to the financial savings, through the improvement of the energetic efficiency or/and improvement of the efficiency of the company regarding environment protection. Implementing the appropriate generated waste minimization measures in any company of this activity, means the previous detailed understanding of every manufacturing processes and operations which include the furniture manufacturing starting from lumber purchasing and ending at the final product shipping.

2. THE PROCESSES AND OPERATIONS IN THE FURNITURE INDUSTRY

The most often, the furniture manufacturing processes include: lumber purchasing, receiving, drying and storage; primary processing and gluing; main processing (machining), sanding and assembly; prefinishing; postfinishing; packing, shipping and warehouse; and

building and equipment maintenance. Fig. 1 presents the flow diagram of the manufacturing processes and materials, from the purchasing stage to the shipping stage, in any company of this industry.

Lumber purchasing, receiving, drying and storage includes lumber receiving and preparing for the next manufacturing processes. These operations are referred to the lumber unloading, quality analysing, sorting, stacking, air (natural) drying, drying in the kiln driven with the boiler as well as dry shed storage. Many of these companies, mostly small and medium, do not conduct most of the operations because they order (purchase) previously prepared and dried lumber.

Primary processing and gluing includes operations like defect removing from dried lumber, its sawing and cutting in rectangle shapes. The gluing and joining operations, which also belong to this operations group, are referred to gluing and joining the ends of short sticks or boards, often with minimum length of 11 cm, in order to obtain longer sticks or tables [1]. Some companies buy dried and cutted lumber with standard dimensions in order to avoid mentioned operations.

Machining, sanding and assembly. The machining operation shapes previously processed wood elements in specific defined dimensions of the furniture part. After shaping, furniture part surfaces which have to be flat are levelled by planars, and before conducting assembly operation, sanded. The last operation is assembly in which furniture parts are put together to make a final piece of furniture by gluing, stapling, screwing, etc. In most cases this process includes fitting, repairing and inspection operations, too.

Before ***prefinishing*** process furniture part surfaces have certain smoothness which can be improve with this process, and one of the improving ways is dipping or spraying with water which causes wood fibbers to swell and rise. After the surfaces are dried, a solution of glue and resin is applied that causes the raised wood fibbers to become brittle, in order to facilitate sanding and obtain smoother surfaces. Some wood used for making furniture contains naturally resin or rosin which presence affects effectiveness of some postfinishing operations, and because of that this furniture part is greased or dipped in a mixture of acetone and ammonia. Once the rosin is removed, the part is exposed to bleaching operation or lightening of its colour by dipping or spraying of its surfaces using hydrogen peroxide.

Postfinishing presents the most complicated and critical furniture manufacturing process after which final product obtains desired smoothness, appearance and glow of its surfaces. The aim of this process is to protect the furniture against accidental scratches and impacts, as well as extend its useful life. Postfinishing includes: coating, drying, sanding, staining or painting, rubbing, polishing, equipment cleaning and final inspection.

Packing, shipping and warehouse. Once the furniture is produced either for interior or exterior usage, the same is packed in order to protect him against unplanned damages and breakages during the shipping to the customer. On the other hand, shipping and warehouse operations are referred to activities which include the usage of equipment for product moving, storage or delivering to the transport vehicle.

Building and equipment maintenance. The implementation of the building and equipment maintenance program provides adequate and continuous production. Regular maintenance activities are: removing worn-out parts and installing new ones; replacing lubricating oils and cleaning equipment from dust, dirt, etc; maintaining and repairing kilns, boilers as well as plumbing and electrical installations.

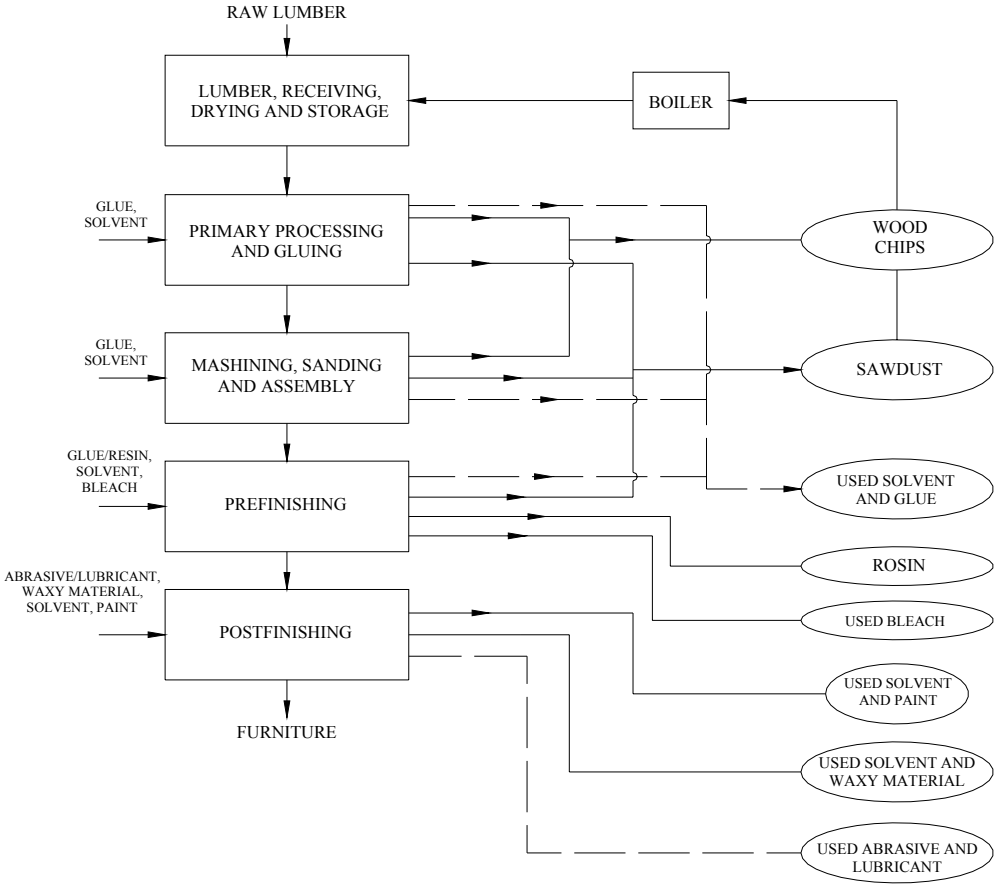

Fig. 1. Flow diagram of the manufacturing processes and materials in a company of this industry

3. TYPES OF GENERATED WASTES, POSSIBILITIES AND WAYS FOR ITS MINIMIZATION AND REDUCTION IN ALL FURNITURE MANUFACTURING PROCESSE

Conducting different furniture manufacturing processes and operations has the aim to obtaining final product (furniture), in which various types of wastes, as a by-products, are generated. Their generating and presence cause land, air and water pollution (Table 1). Sawdust, volatile organic compounds and other particles affect to air pollution, while various solvents and materials used specially in prefinishing and postfinishing processes affect to water pollution. Solid waste as wood chips, used filters, coatings with passed lifetime, empty containers or cans of solvents, solutions or coatings, adhesive wastes and resin wastes presents a big problem in environmental protection tendency specially of their disposing to the landfills. Among all other things, mentioned generated waste has the highest impact on the employees who are directly exposed to the damaging emissions as a

consequence of conducting different manufacturing processes. Implementation of the measures for the reduction of generated waste contributes to increasing of the efficiency and profit of a company, through the reduction of the material quantity and raw materials as the inputs in every production process, reorganisation of the production processes with tendency of higher reusing of the following by-products, better management and process organization, etc.

Lumber purchasing, receiving, drying and storage. There are many techniques for minimization of the waste generated in this process that are related to the proper and effective planning and organizing of the lumber purchasing and receiving operation, effective and smart quality analysing and sorting, separating lumber layers by kiln sticks, improving efficiency of boiler that driven kiln, improving drying kiln efficiency, air vacuum drying, vacuum press drying, radio frequency drying of veneer and adequate dry shed storage.

Lumber purchasing is in tight connection with the final product designing operation and choice of material which will be used for final product production. The companies, which have a design office, have the ability to design, which will require less raw materials usage, choice of materials and raw materials which have less or no impact on the health of employees and the environment and that can be recycled. The Senator International Ltd (UK) company reduced generated wood waste by designing the final products in a way that its components require the purchasing of the lumber with the shape that is approximate with final product shape [2]. When it comes to the choice of materials, it should be keep in mind that in some situations material can be selected in a way that it whole or in part can substitute previously used material, and which is both cheaper and environmentally acceptable [3]. Charnwood Upholstery Company Ltd (UK) decided, during 1999., that the material, birch tree, replace with other material, which contributed to reduction of the generated waste costs by 80% and annual savings of £12,000 [2].

Table 1. The impact of the generated waste from furniture manufacturing on the environment

Manufacturing process	**Pollution**		
	Water	**Air**	**Land**
Lumber purchasing, receiving, drying and storage	-	✓	-
Primary processing and gluing	✓	✓	✓
Machining, sanding and assembly	✓	✓	✓
Prefinishing	✓	✓	✓
Postfinishing	✓	✓	✓
Packing, shipping and warehouse	-	-	✓
Building and equipment maintenance	✓	✓	-

Purchased lumber are often transported in packages containing wood boards or strips of different length, thickness and quality. Smart determination of its quality and sorting avoiding the generation of waste. Upon receiving of the lumber package, it is advisable to determine its quality and sort it by length, thickness and quality, which effectively saves and organizes the space around the company, increases the efficiency of drying kiln, avoiding empty and unused spaces, and thus increases the productivity too. Also this reduces the risk of formation of defects during the drying or breakages as a consequence of movement of long

boards or strips during its packing.

Once the received lumber is wrapped in a way that the wooden strips or boards are stacked one on another. Such lumber stacking can result in the occurring of spots or stains on lumber surfaces or even rot, which currently threatens its quality and contributes to waste generation. Because of these reasons sticks of certain dimensions (2.5 m x 40 mm and 25 mm [4]) are introduced, so called "sticks separators" which separate the lumber in layers, which enables more efficient natural lumber surfaces drying. It is also necessary to take care of the distance and mutual position of the same sticks, because lumber packets closer to the ground are burdened by the weight of the package above, which can deform and damage them and cause waste generation.

During the lumber drying in kilns driven by boilers, it must be paid attention to their functioning as the boilers are one of the major air pollutants in the furniture industry. On the other hand, its inefficient functioning impacts on reducing company productivity and thus the increasing of total costs. The type and amount of emissions from boilers, affects furnace construction, its operating conditions, the degree of flue gas recirculation primarily of ash (if such a system exists) and the type of used fuel. When it comes to used fuel type, for these boilers the clean wood waste from the manufacturing processes is mostly used fuel. The furnace construction and its operating conditions have a major impact on emissions of boilers that use wood waste as a fuel. Besides that, often in the mentioned boilers secondary air stream is introduced above the layer of fuel to promote combustion of volatile compounds in the fuel. If the fuel combustion is incomplete, it may result the firing temperature lowering which causes the emission of particles, CO and other organic compounds. In large boilers are also installed systems for particle separating and recirculating of ash, such as cyclones, electrostatic filters, scrubber and bag filter systems, which increase the fuel combustion efficiency and the degree of particle separation. In addition, boiler efficiency increasing can be achieved with adequate maintenance of boilers, related devices and equipment (valves, pipes, heat transfer areas) and with adequate insulation of boiler and pipes [1.4].

If the lumber is dried in kilns it is recommended that the same operate at optimal capacity. Maximum capacity kiln operating prevents the circulation of air inside it that drags along inadequate lumber drying, the higher drying time, and with it the higher energy consumption, higher emissions and higher costs. On the other hand, if they operate at minimum capacity (10-50% of its capacity) the air circulation will be greater, the drying time less, but productivity will also be lower with higher energy consumption and associated higher costs. Increasing the speed of air circulation within the kiln two to four times will reduce lumber drying for two to three times. By increasing the air speed using fans shorter drying time and better quality of dried lumber is achieved. It is recommended to use variable speed fan, which in the initial phase of drying, provides the maximum amount of air, and in the phase when the diffusion of water molecules from the wood considerably is slowed down the minimum amount of air, without disturbing the operation of drying [1.4].

Air vacuum, electrical resistance vacuum and press vacuum drying are relatively new technologies of lumber drying. They involve the use of hot air and vacuum, electrical resistance blankets placed between lumber layers or a mechanical pressure of 0.5 bar, respectively [1.4].

Upon lumber drying it is necessary to use it faster or store it in a special dry and closed storage, in order to prevent its damage caused by the influence of external weather conditions or activities within the

company. If the dried timber is in storage for several months, it is necessary to ensure the environment control within the same [4].

Primary processing and gluing. The execution of these operations leads to waste generation in the form of wood chips, sawdust and adhesive materials remnants. The possibilities for waste minimization and reduction of its negative environment impact are referred to the effective defect removal from dried lumber, higher end joining of the short boards or sticks, recycling waste chips and sawdust, the use of proper and adequate adhesives and adequate gluing techniques.

Effective defect removal from the lumber surfaces involves cutting different lumber lengths. New technologies that ensure the effective performance of this operation, identify defects are developed, such as computerized scanning technology [4]. Applying the end joining operation, the company Richard Burbidge Ltd (UK), which annually processes more than 50000 m^3 of wood, significantly reduced generated waste [5]. Often in practice can be found that the wood waste is used as fuel or disposed to the landfills. As prices of wood and wood waste disposal from year to year rise, many solutions for its reusing or recycling, and also using as a raw material in other industries, like energy or heat source, are found. Wood chips and sawdust during the performing of these operations can be postponed and later recycled in companies which produce plywood boards, laminates, paper and pulp, or reused in the company area or in another place and company as an energy source with or without combination with other waste. An example of the use of wood waste as raw materials in the recycling process can be found in the Welch Biofuels company (UK), which among other products produces wood pellets 8 mm in length. Wastecycle company (UK) buys wood waste, grinding and prepare it for the plywood boards and laminates production [5].

The use of appropriate adhesives also presents a way of reducing waste. The most often mistake in small companies of this activity is inadequate and wrong adhesives applying. Some adhesives are irreversible and can not be transferred into the liquid and reused. On the other hand, inadequate and improper gluing also generates waste. Particular attention should be paid to the gluing techniques execution.

Machining, sanding and assembly. During the execution of the machining and sanding, comes to waste generation in the form of wood chips and sawdust. The waste minimization can be achieved using the segmented polishing platens, system for collecting sawdust, cleaning machine tools used to perform these operations as well as recycling waste.

Wood chips can be used as a source of energy and heat in boilers or recycled in a completely identical way as the waste generated during the execution of the primary processing. The Senator International Ltd company (UK) installed 1.4 MW boiler driven by combustion of wood waste from production processes which resulted the reduction of waste disposal cost to £70,000 per year and gas bills to £20,000 per year. Boiler is used for company heating [5]. The segmented polishing platens dramatically removes less material, during sanding, which contributes more material saving, waste reduction and thus reducing waste disposal cost. Besides the wood chips, the waste that occurs in large quantities is sawdust, which has a very negative impact on air pollution and health of employees. It is removed by aspiration system (local or central system of pipelines, canals, fans and various types of filters). Their use increases the sanding efficiency because it prevents the entry of sawdust in the sanding tools and machines, as well as increasing their lifetime. They also prevents contact between sawdust and dirt

which the possibility of its reusing or recycling is provided [4]. Speaking of the possibilities and ways for generated waste reduction during the execution of the assembly they are referred to the recycling and reusing of the wood chips and sawdust, use of proper and adequate adhesives and gluing techniques, which have been previously described.

Prefinishing and postfinishing. Gaseous, liquid and solid waste is generated during the execution of these processes. Gaseous waste is associated with the emission of volatile organic compounds, sawdust and other gases hazardous to health and the environment. Liquid waste involve used solvents and materials in prefinishing, painting/staining, fillers and sealers, various coatings, materials for rubbing and polishing and waste waters, while the solid waste includes used filters in the applying coating chamber, cloths and fabrics, containers and cans with solutions and materials, etc.

Applying alternative coatings, reliable and efficient technologies as well as adequate planning and organization of manufacturing and maintenance operations it is possible to reduce generated waste. The alternative coatings include materials with water as solvent, high solid solvent based coatings, polyester/polyurethane, CO_2 based coatings and radiant cured coatings. The Shuttery Nanik company (USA) reduced emissions by 85% and save $32000 per year by using water as solvent [6]. The Ethan Allen company (USA) reduced emissions of volatile organic compounds by 28%, labour costs to $175,000 annually and generated waste by reducing the required amount of material given in the amount of $42000 annually by using high solid solvent based coatings [6]. Drifting the polyester/polyurethane based coatings Geiger Brickel company (USA) reduced emissions of volatile organic compounds by 25% while increasing quality and productivity [6]. Pennsylvania House (USA) company reduced emissions of volatile organic compounds by 70% and the amount of required material for 50% installing CO_2 based coatings equipment [4]. Substituting the polyurethane based coatings with radiant cured coatings Hussey Seating company (USA) saved yearly around $55000, and in labour costs about $280000 [6]. The reliable and efficient applying coatings equipment involves "flat-line" technique, spray technique and technique of dipping furniture pieces, vacuum and flow coating technique. Purchasing and using the "flat-line" technique using rollers, the Steelcase, Inc. company (USA) reduced the need for coatings and increased productivity 2-3 times while reducing emissions of volatile organic compounds [7]. The Kernp Furniture Industries company (USA) using airless-spray technique saved annually 23% of coatings compared to the previously used air-spray technique [7]. Experience of Ethan Allen company (USA) on using a low pressure and high-volume spray technique tells that it is possible to reduce the required amount of coatings by 39% with a simultaneous annual savings of $145000 [7]. Broyhill Furniture Industries company (USA) reduced purchasing coatings costs by 25% and the need for labour using the electrostatic spray technique [7].

Adequate planning and managing manufacturing and maintenance operations is associated with the need and ability to train employees, adequate coatings preparation, direct coatings transfer to spray technique, the use of thermal energy for desired coatings viscosity obtaining, maintenance of production equipment and devices, management of raw materials and recycling of used materials.

The employee training is considered as a permanent communication between employees about the goals and expectations of the company related to the efficient production, reducing generated waste, energy consumption, safety, etc.

Employees must follow the instructions about using production equipment and devices, related either to the value of working pressure, the concentration of coatings, flow rates or maintenance [6]. Training the employees the Ethan Allen company annually saved 8-10% in the required material quantity ($50000-70000) [6].

Inadequate coatings preparation can lead to increased use of materials and waste generation. It is essential that solvent has to be added to coatings, not opposite to that. Moreover, solvent adding should be relatively slow, with simultaneously monitoring and quality analysing of the mixture.

Regular maintenance of production equipment within the postfinishing process prevents its possible damaging, its irregular and unreliable operation, as well as waste generation. Spray compressors has to set up in places where it is possible suction of fresh air. Maintenance of production equipment also includes pump maintenance to prevent leakage of working medium. During the coating chamber cleaning it is recommended not to use different types of coatings because it can result in a spontaneous outbreak of fire, as well as obtaining the waste, from a mixture of different materials, that can not be recycled or disposed to landfills [3].

The establishing of management control of raw materials enables reducing waste generation, related costs and increases available space for storage or work through establishing and maintaining close contact with suppliers and manufacturers of raw material in order to avoid the situation that a certain amount of them fail or become waste due to non-use [7]. Used coatings can be recycled by different technologies. One of them is the coatings distillation as well as many others which prolongs its life. It is recommended that the solvents used for equipment cleaning and maintaining, and waste waters from the distillation process, where it is possible, be reused as coatings of lower quality requirement. Installing a distillation unit the Ethan Allen company recycles 19 l of 27 l of solvent that is introduced into the distiller and saves $3200 per year [6].

Packing, shipping and warehouse. Much attention in recent years is focused on finding solutions and possibilities for reducing generated waste during the execution of packaging, transport and warehouse operations. Improving packaging operation through the establishment of the damage furniture pieces evaluation and moisture resistance evaluation of packed final products, reducing the content of toxic metals and eliminating the ozone destroying substances from packing materials, redesigning the package to reduce its weight and volume, development of reusable containers, using materials that can be recycled and recycling other generated waste in these operations can minimize the generated waste.

The used materials in furniture packing will be reused, recycled or disposed in landfills. If there is an intention to recycle or dispose them it must be determined is there any presence of toxic substances as the result of the use of ink, oil or paint for marking package. In relation to that packing materials producers should possess a certificate that will guarantee that such materials do not contain toxic substances (in the form of mercury, lead, cadmium, etc.) or that they are in the permissible limits prescribed by certain regulations. The same is applied to materials that contain ozone destroying substances [4].

Redesigning the package to reduce its weight and volume, manufacturer will for the same furniture have a lower energy consumption during package production, less use of raw materials, less labour and shipping costs as well as less waste. Therefore, materials that are lighter and occupy a smaller volume of the entire

package are developing. In recent years the cardboards that are lighter, cheaper and recyclable replace wooden pallets, contributing to annually savings of $145000 [4]. At the same time bioplastic material as plastic materials produced in the glucose fermentation in the presence of bacteria are developing. Their biggest advantage is that they present renewable sources (corn) and that are the biodegradable in anaerobic conditions in the presence of bacteria. But for now, their biggest disadvantage, which limits their mass use, is that the cost of their production is about 10 times higher than the production costs of conventional plastic materials [4]. No matter what type of material is used, wood, plastic, paper or bioplastic, it should intend to reduce weight and volume of packages, that they are reliable and can be reused or recycled.

In a situation where it is impossible to reuse packing materials the possibility of its recycling it is considered. Packing materials that are commonly recycled are plastics (polyethylene, polypropylene) and cardboards. The problem that arises with its recycling refers to the collection of recycling materials and its delivery to recycle plant. In some countries, there was the idea to encourage and persuade customers to pack empty packages in a separate bag or box and send them out to the same company which will return their spent postage money later. Particular attention with recycling is paid to the extent of the self-adhesive tapes or adhesives in the total weight of packaging materials. Implementation of the various tests led to the conclusion that if the presence of these substances in the total weight of packaging material is no more than 2% they will not affect the recycling process.

Building and equipment maintenance. The possibilities for reducing generated waste during these operations are related to the use of synthetic lubricating oils with longer lifetime compared to the conventional, its recycling, kiln maintenance, cleaning of spilled oil with recyclable absorbents, sorting of waste in order to recycle them later or prevent outbreak of fire, recycling of wood, metal, glass and paper and use the boiler ash in agriculture [8].

4. CONCLUSION

Various mentioned ways and possibilities for waste minimization in the furniture industry, as already mentioned, contribute to the company profit increasing, as well as reducing the negative impact on the environment of executing their activities. The reasons have weight due to the intention of our country to become EU member, which imposes us obligation of fulfilment all the stringent requirements related to environmental protection. Within the EU a directive on waste disposal in landfills is adopted, which regulates the disposal of biodegradable municipal waste, which will certainly include the future biodegradable waste from the furniture industry. In Denmark and Netherlands regulations prohibiting the disposal of waste in landfills are adopted [2]. It should also bear in mind the existence of the directive on furniture packing which regulates the disposal of this type of waste. One of the reasons for intensify efforts towards finding and implementing solutions for waste minimization in this industry is the fact that the need for wood in the period from 1990 to 2010 is increased by 26% [2]

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