Architectural Environmental, And Process Flow in Constructing Modern Factories for Manufacturing Eco-Friendly Furniture

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Abstract. Today, a dominant trend in factory construction is to account for the eco-economic aspects of their further operations. It requires sustainable technological solutions, with regard for structural specificities or for production technology used. At the same time, the buildings shall be architecturally attractive and distinct. In the paper, the author considered architectural, technological, structural, ecological, and economic factors for construction of wood-processing and furniture-making facilities. The author analyzed the actual Project Design to build the type of facility in Krekhiv village, Zhovkva district, Lviv region (western Ukraine) as commissioned by a well-known French company (the author have been engaged in the design). The study focused on a wood-processing Woodman company designed for the midtech production of edge glued panels and furniture. According to the design documentation by types of products planned, the Project Design provided for the following production units: unit for wood-sawing and drying; unit for mechanical processing of wood, production of edge glued panels and furniture; unit for mechanical repairs; and an administrative and services unit. The anticipated annual production capacity is: for edge glued panels – 600 m³ a year, furniture production – up to 4,000 pc a year.

“Wood-sawing unit”, according to the Project Design, is organized according to the following principles of production technology based on the stages and operations: stockholding and storage of round timber (sawtimber); cutting the sawtimber into the shaped timber and logs; stocking the sawn timber (untrimmed boards) into stockpiles and on separators for further atmospheric and chamber drying. Sawn timber drying is taking place in the “Drying Unit”. It is the process of moisture removal from timber to a certain degree of humidity. The Project Design provided for the atmospheric drying of logs and boards in the furnished stockpiles under the roof, and artificial seasoning in a steam-curing and drying chambers. The artificial seasoning technology for sawn timber and logs is organized with the help of drying chambers and a boiler room with a sawdust bunker. The “Unit for Mechanical Wood Processing, Production of Edged Glued Panels and Furniture” is used for production of the edged glued panels from the sawn timber coming from hardwood (beech, oak). The production process of the edged glued panels includes the following stages: 1) cross-cutting of dry boards; 2) line cutting of board edges for the rough-sawn stock; 3) primary mechanical processing; 4) sorting by quality, color; 5) end-jointing gluing line; 6) log finishing; 7) press-molding of logs into panels; 8) panel surface preparation; 9) size cutting; 10) preservative treatment; 11) quality control; 12) storage and sales. “Administrative and Service Block”, according to the Project Design, is an inbuilt part of the Main Building (Unit). It is a two-story insert separated with the fire safety barriers from the manufacturing facilities. It has isolated outside entrances and a technological corridor linking the manufacturing facilities. With account for production process requirements, fire safety, and sanitary standards, the Unit is divided into several personal services rooms for the staff and administrative rooms.
1. Introduction
When constructing industrial facilities, architects and engineers usually overlook any further prospects for future modernization of the technological process at the company since the technical procedures in most factories are progressing much faster than designing and engineering approaches. In fact, the project designs for industrial facilities have been unchanged over the recent 50 or 70 years. They do not require to account for flexibility of internal spaces for prospective technological improvements of the manufacturing processes or for entire change of functions.

The author of this research (Candidate in Architecture and a practicing architect S.O. Ivanov-Kostetskyi) relies on his practical experience in designing industrial facilities and says the investors set the “Designing Terms of Reference” in the beginning of design works. There, they usually focus on the optimization of the future facility, and request to apply a reasonable approach to communications and engineering networks (such as HVAC ducts, fire safety systems, or lighting systems of the work stations). In other words, investors are searching for ways to save construction funds through the means of architectural and engineering design focusing on energy-efficiency and integral energy monitoring during further operations of the facility [1].

In 2017, the author of this research read the works by a Russian architect Ludmyla Borysivna Kolohryvova, such as the Patent No 1728448 [2] on a new form of a building for industrial purposes. Despite the fact that the patent holder considers machine building and instrument making industries, the author of this research posits that the forms of buildings could be broadly used also in other industries. The simplicity of “novel forms” that has been implemented by L.B.Kolohryvova since the 1970s is based, in my view, on simple resource-saving criteria. Specifically, the building may consist of two or three key elements: 1) central core with engineering networks, sanitary blocks and motor and foot traffic flows fort the staff; 2) manufacturing facility that encircles the central block and makes a spiral of platforms and ramps, which length can be regulated depending on production programme; 3) administrative and service block that could be located above the central core and also added to one side of the manufacturing facility [3].

2. The architectural, technological, structural, ecological, and economic factors for construction of wood-processing and furniture-making facilities
The author of this research S.O. Ivanov-Kostetskyi is a co-founder and an architect-in-chief at the “KREATIV AIC” LTD architecture practice [4]. The practice, as supervised by the author, designed and built a series of industrial facilities in Ukraine based on the principles described above, the wood-processing facility of the Woodman company among them. According to the Project Design, it was designed for midtech production of edge glued panels and furniture in a village of Krekhiv, Zhovkva district, Lviv region (western Ukraine), as commissioned by a well-known French company.

The design project for the “Woodman Factory Construction” implied several structures that combined into the integral arrangement and an engineering and manufacturing process for making the edge glued panels and furniture. According to the specifications for a project design by types of products to be manufactured, the Project Design foresaw the following production units: wood-sawing and drying units; a unit for mechanical wood processing, production of edge glued panels and furniture, a mechanical repairs unit, an administrative and services unit, and several auxiliary buildings and structures: front security entrance, fuel depot, boiler room, sewage treatment facilities, advertising tower, flagpole, and the 400 kW transformer substation. The factory’s planned annual capacity is the 600 m³ edge glued panels and up to 4 000 units of furniture a year.

“Wood-sawing unit.” The process flow diagramme for the production at the wood-sawing unit includes the following stages and operations: a site for stockholding and storage of round timber; sawmill unit to cut the round timber into the sawn timber and unfinished stock; a shed for stockpiling and storage of sawn timber (untrimmed boards) into stockpiles and on separators for further atmospheric drying; boxes for chamber drying of untrimmed boards.
“Round Timber Site” is located on the axis of the main entrance to the premises. In front of the site, a plowed area is planned for the convenience of motor vehicles unloading the round timber. Round timber and sawn timber shall be delivered to the open storage facility (site) by motor transport. The unloading shall be administered by a vehicle-mounted crane. The distance between the timber stockpiling site complies with the standard fire separation for buildings and structures – 12 m.

“Sawmill” is located in the site’s center, near the “Round Timber Site.” It is located on the axis of the main entrance to the premises to ensure simple links between the processes. At the “Sawmill,” they conduct the primary cutting of round timber. Log cutting is conducted at the industrial line with the remotely operated horizontal chainsaw tool and the automated relocation of the sawn timber. The uploading of logs is performed from the hydraulic accumulating ramp equipped with a special device for single-piece output of logs. The finished boards are claimed from the tool onto the inbuilt conveyor belt. The sawn out timber may be in for either length cutting or cross cutting on an edger-resaw tool or a trimming tool. The offcuts of slab wood, wood lath, and chopping are put into bunch sets and used as fuel. The sawmill includes one facility with three gates and a door for the staff.

“Sawn Timber Stockpiling Shed” is located opposite the “Sawmill” to enable the uninterrupted technological process of wood processing. After the “Sawmill” the produced boards and semi-finished stock are sorted and stoked into piles with separators, to be further stockpiled by a forklift for further atmospheric drying of the materials. The shed is a structure that is comprised of the support columns, with no walls or roofing (protection from direct weather elements such as rain or snow).

“Chamber Drying Units for Untrimmed Boards” include the following two subsequent stages: Drying Chamber and Steam Curing Chamber. The “Drying Unit” is located along the line with the “Stockpiling Shed for Sawn Timber.” It creates the back-to-back technological processes to prepare the timber. “Drying chamber” is a rectangular building in plan view, made of a set of finished elements ready for assembling. They are columns, wall sandwich panels, gates, beams, and roof sandwich panels. The structure has been produced under the technology of the Le.Ko Sp.z o.o. (Poland). Structural erection and assembly shall be performed by the manufacturer’s representatives. Before the erection, a foundation base will be made, with the required technological penetrations and channels for connection. “The “Steam Curing Chamber” is a stand-alone smaller structure but schematically similar to the drying chamber. The process of timber and log drying includes the following technological and control operations: identifying the initial and current humidity of timber; designating the drying mode; uploading the chamber and initial warming of timber; managing the drying chamber; control over the drying schedule and timber status; timber heat and moisture treatment; conditioning of timber.

For color balancing of beechwood and for phytosanitary sterilization of sawn timber, it is planned to have a steamer in this section (type LK-PR-25, LeKo, Poland). The LK-PR-25 steamer is designated for direct steaming of timber with the loading capacity of ≈ 25 cubic meters, with 35% tier load. After the steaming, tiers are transported to the warehouse for atmospheric drying, or loaded into the drying chamber for further drying targeting the set end humidity. Convection heat drying of timber is performed in the convection-type drying chamber LK-ZDR (LeKo, Poland). Four-chamber drier LK-ZDR-4x50 is designated for the drying of timber with the convection method, with the load capacity of ≈ 4x50 cubic meters, with 35% tier load (4x60 cubic meters of the 50 mm trimmed timber). Chamber drying of sawn timber includes a series of technological and control operations. The technological operations of the drying process include the following: stockpiling the sawn timber, preheating, administering the drying process according to certain schedule, interim and conditioning heat and moisture treatment. The drying process is undergoing the continuous control and regulation of temperature and relative humidity of environment, and the intermittent monitoring of timber humidity. Transportation of dried boards to the unit of mechanical timber processing in the section of the dry timber warehouse is done by the fork lift.

“Unit for Mechanical Wood Processing, Production of Edge Glued Panels and Furniture” is located in the main production building that includes two sections: “Production Section” (storage facilities, technological facilities for wood processing, and a group of facilities for furniture production), and the
“Administrative and Services Section” with the inbuilt dining hall of the canteen with the service counter, with the capacity of 28 seats. The main production building is a one-story structure, 72x72 m in size, located in the center of the production area. The production process for the edge glued panels in the “Production Section” includes the following stages:

1. Dry board cross cutting for the ToR sections.
2. Cutting of the deal ends into the rough-sawn stock (line cutting), sorting by size and wood species.
3. Primary mechanical processing of the rough-sawn stock, four-sided shaping, sorting by quality and length groups.
4. Optimization (cutting off the defective spots: knots, beetle damage, rote of wood, colored spots, etc.). Sorting by quality, color, and other features.
5. The line for end-jointing (shaping machine and the end-jointing press with the trimmer and glue spreader). Production seasoning for glue polymerization.
6. Clean finishing of rough pieces on the four-sided shaping tool. Storing of lamellae for further gluing into panels, according to the specifications.
7. Pressing the rough pieces into panels on the assembly pressing machine, stacking the panels after gluing for the production seasoning.
8. Preparation of the panel surface on the calibration-rubbing machine.
9. Sizing or (if required) cutting into panels of other sizes, or into sections.
10. Preservative treatment (finishing) of panels.
11. Quality control, stacking and packaging of panels, storage and sales.

The furniture production is based on the use of edge glue panels and parts made of natural wood produced at the factory. Manufacturing furniture of this type of materials (semi-finished parts) qualifies as the highly modern technology complying with the high functional (operational) and aesthetic requirements. Moreover, it ensures maximum shape retention for articles made of natural wood, as well as strength and eco-friendliness. The process flow scheme in furniture production includes the following operations: cutting the materials into the rough pieces by dimension-types; mechanical processing of rough pieces into the set dimensions by thickness and width for dimension blanks; shaping, polishing of blank pieces and preparation for decoration; painting and varnishing; assembling the furniture, marking the articles, sample control, industrial packaging.

Main production facility is located on the level of the same floor within the “Production Section,” and includes the following production units:

1. “Dry Timber Warehouse” is designed for storing of the inbound timber. Materials and parts are stored on the pallet and shelf racking.
2. “Mechanized wood processing section” includes the following operations: cutting the materials into the rough pieces to size; mechanical processing of rough pieces by thickness and width for the blank pieces; scuff sanding, shaping, polishing of blank pieces and preparation for decoration; painting and varnishing; assembling the furniture, marking the articles, sample control, industrial packaging.
3. “Storeroom for constituent elements” is an isolated room with racks to place the constituent elements for wooden ware.
4. “Products Assembling Section” is designated for assembling the wooden ware. The section includes a pneumatic assembly machine, work stations and a wide range of electrified hand tools. The parts are assembled with the help of tenon joints, screws, clamps, braces, bolts a.o. The knots assembled of parts shall undergo the mechanical re-processing.
5. “Polishing Section” – the production process of polishing takes 15 to 20% of the overall labour input in manufacturing the products. Therefore, the issue of work efficiency in the polishing section is of high importance, the same as the quality of work, since the product appearance is made here.
6. “Section for painting, varnishing, and natural linseed oil impregnation” implies the paint and varnish implication, both for translucent coating to keep the wood texture, and for opaque coating, without keeping the wood texture. The sequence of finishing operations is as follows: surface puttying on the basis of the fine grade sawdust with binders (e.g., PVA glue); sanding product
surfaces; priming stain; interim sanding of primed parts; varnish or paint implication in paint-spraying booths. Upon drying, the finished parts and products will be transported in hand carts to the stacking section, or to the finished products warehouse.

7. “Section for preparing and storing paints and varnishes” is an isolated room where painting and varnishing materials are prepared to be used for coating of finished products. The section also stores paint and varnish bases.

8. “Packaging Section.” Upon drying, finished parts and products will be transported in hand carts to the assembly section. Process-wise, in this section, finished wood products will be packaged.

9. “Finished Products Warehouse” is a combined space with the “Packaging Section.” However, for safety reasons, it is separated with a 2.5 m high metal mesh. The warehouse includes racks to store finished products.

To allow natural lighting for the “Manufacturing Section,” roof lanterns have been designed. They are partially made to open – to release smoke in case of accident or fire. The staff will get to the “Manufacturing Section” across the corridor to the staircase. In addition, 3 emergency exits from the “Manufacturing Section” have been designed.

Administrative and services unit is inbuilt as the 2-level insert into the main manufacturing facility, and separated from production facilities with fire safety barriers. It has the isolated outside entrances and the technological corridor linking the manufacturing facilities. With account for production process requirements, fire safety, and sanitary standards, the Unit is divided function-wise into a section with service rooms for the staff, and an administrative section. The factory’s operational staff have changing rooms and sanitary and amenity facilities, according to the production process groups. The service section is located on the ground floor of the “Administrative and Service Unit.” It has a separate outside entrance and a service passage through the corridor to the “Manufacturing Section.” The service facilities include changing rooms, showers, wash-rooms, and lavatories, smoking room, and a training classroom. For catering of the staff, a closed-type dining-hall with a service counter has been designed, to host 28 seats.

“Canteen” is a closed-type facility selling the supplied finished food to cater for all the company’s staff in 2 rounds. The Canteen is located on the ground floor level, in line with the “Administrative and Service Unit” and has a separate outside entrance and a convenient connection with all rooms of the “Manufacturing Section” through corridors or stairs. Canteen visitors will self-cater for themselves through the service-counter. The “Canteen” section includes the following rooms: a dining room with 28 seats, and a service-counter, canteen back room, dish washing room, changing room for the staff, lavatories for the staff.

“First Aid Room” is designed for offering first medical aid to the staff. It is located on the ground floor as a separate room. Basic medical care for the staff shall be administered at their local clinics.

“Administrative Sections” are located on the second level of the “Administrative and Service Unit” as functionally separated facilities from amenities. The left wing hosts the rooms of the pre-production unit; the right wing hosts the central offices, accounting office, and a secretariat. Work stations of the office staff are equipped with computers. Administrative and engineering-technical staff are provided with the changing room and sanitary amenities and facilities. All the offices have the changing lockers installed. On the second level, there are isolated toilet facilities separated by gender; and a meals room is designed for individual meals.

“Repairs and Mechanical Section” is implemented as a garage building for storage, maintenance and repairs of the factory’s custom machinery such as a tractor, or an onboard truck. The garage is located near the front security entrance at the entrance to the premises. The garage is divided in plan into two modules: 1 module for storage and repairs, with an inspection pit in one of the workshops of the module; module 2 is a workshop with the vehicle wash equipment, including the ramp for water
collection in the center, and a system for water treatment and recycling. Each workshop has an autonomous entrance through the 3.5 m wide gates (3.3 m high).

“Front Security Entrance” is located at the entrance to the factory’s premises. It is used to control the territory and for security of the factory’s buildings. The Security Entrance includes the “Control Point” with 3 turnstile that could function both for entrance and exit to and from the premises, the guard’s accommodation with a fixed glazing and the door to the control point, toilet facilities with a handwasher and a toilet bowl for the staff of the Security, Fire Service and the Garage with 3 cells, an air-lock corridor in front of the entrance to the toilet room, and the room of the “Fire Post.”

“Car park for staff and visitors.” According to the estimates, the factory needs at least 5 parking slots, including also 1 slot for people with limited mobility. The car park for the factory’s staff and visitors is designed not far from the main entrance to the premises, at the Front Security Entrance, behind the Garage building. The car park is planned for 7 parking slots, with one slot including an additional lane (1 m wide) for boarding and deboarding of passengers with disabilities.

“Underground Firewater Tank” consists of plastic containers connected with each other and with a reinforced-concrete tank of the pumping unit. All containers are located below ground and covered with a 1 m layer of soil. The design marks above the containers are made on the same level with the general planning concept of the territory.

“Transformer Substation 400 kW” is a finished metal structure delivered to the site fully finished. Before the assembly, the foundation base will be made, with the required technological penetrations and channels for connection.

“Boiler and Fuel Depot” consists of two separate blocked buildings. The building of the “Fuel Depot” is rectangular in plan and consists of two rooms: the fuel depot and the machinery room. Sawdust is supplied to the fuel depot through the gate in the wall, then the “live bottom” machinery is evenly pulling up the sawdust to the screw type conveyor further transporting the sawdust to the boiler room, and supplies sawdust to the boiler. The “Boiler” building is interlocked with the “Fuel Depot” and technically and continuously connected to it. The rectangular structure consists of the boiler island, the inbuilt operator cell, and the back room.

“Flagpole” is a structure in the shape of a foundation base with 4 beds to host four flagpoles. The poles are made of the stainless steel 6 m high, produced by “Mokhiy” company (Ukraine). The flagpoles are designed to have the additional landscape illumination.

“Advertising tower” is a structure in the form of a flat vertical advertising stela, 4 m high, 25 cm thick. The stela is comprised of a metal frame from the bend-closed profile, plastic paneled, and the lighting in the ceiling.

“Sewage treatment facilities, separately for sanitary wastewater and for other discharge” are made as separate underground structures delivered in a finished form, produced by “Standardpack” (Ukraine). All containers are located below ground and covered with a 1 m layer of soil. The design markers above structures are made on the same level with the general planning concept of the territory.

3. Results and discussions
The alterations in the technological processes of many production facilities are possible upon their completion (the author relies on his own experience in building the objects). It is due to a fast progress in global industry. Therefore, all necessary improvements have been introduced in the technological processes, for better performance indicators or for adjustments in operations vectors. The changes lead to modifications of the available engineering networks and fire safety systems. This kind of optimization of companies after the completion of construction works suggests the need to apply the methods declared back in 1970/80s by Doctor of Architecture, professor of Moscow University Kolohryvova L.B. In the
concept, the design used the buildings of circular or other related forms, with the production process structured in spiral order implying technological and engineering flexibility.

4. Conclusions
The paper presents a model of an eco-friendly wood products factory on the basis of methods to structure technological processes and buildings suggested by L.B. Kolohryvova. It illustrates the actual project design solutions that could be a basis for further design of wood-processing companies since the principles used have been confirmed and economically justified when building the production facility described in the paper.

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