I J PME International Journal of Production Management and Engineering

https://doi.org/10.4995/ijpme.2020.12360
Received: 2019-09-19 Accepted: 2020-01-21

Feasibility Study of a Facility to Produce Injection Molded Parts for Automotive Industry

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Abstract: This study aims at the preliminary assessment in designing a complete stand-alone industrial facility to produce injection molded parts for the automotive industry. A draft design solution to allow the company to evaluate the capital investment was performed giving an estimated solution in project profitability. Proposed successive design steps were developed. It includes the definition of input data and information, quantity determination, plat layout diagrams, machine selection, selection of material handling equipment, plant layout design including space requirements of production centers, aísles, support functions. Moreover, the outdoor facility masterplan design is also proposed. Finally, investment calculation via cash flow analysis is calculated.

Key words: feasibility study; facility design; plant layout design.

1. Introduction

Facility layout design has been considered as one of the essential aspects of a company to have a significant reduction in the operational costs of the firm (Kovàcs, 2019). The proper planning of the overall layout production plant needs to be deeply conducted as the first step of a company to run the business. However, everything starts with an assessment of the planned business area in terms of the practicality of a proposed plant of the business sector. A preliminary feasibility assessment has been widely conducted as the first, foremost step before starting a business or developing projects (Hwang et al., 2019, Halil et al., 2016, Ma et al., 2019, Eksangsri and Jaiwang, 2014, Chingua et al., 2019). The main objective of a feasibility assessment is to 'de-risk' potential full trial funding (Morgan, 2018). Considering some assessments in the feasibility study performed by mentioned researchers, this research activity can mainly provide reassurance and potentially avoid waste and to obtain an answer to the project in question of the company, which in this case is especially applied in the automotive sector.

The complete work is to develop a feasibility study aimed at the preliminary design of a complete stand-alone industrial facility to manufacture aluminum alloy and injection molded parts for the automotive industry. However, this study is one part of the complete feasibility analysis of the plant. This paper focuses only on the production of injection molded parts. In this case, the industry is planning to manufacture bumpers, car dashboards and wheel arches. The mentioned facility comprises a fully-equipped production plant layout, raw material storage, work in process areas, finished product warehouse, auxiliary materials warehouse, and

To cite this article: Yudianto, A., Tan, H., Qu Z., Xue Q., Naveen A.C., Mushtaq, M., Gopi K.S. (2020). Feasibility Study of a Facility to Produce Injection Molded Parts for Automotive Industry. *International Journal of Production Management and Engineering*, *8*(1), 45-57. https://doi.org/10.4995/ijpme.2020.12360

auxiliary function spaces. A complete masterplan design for both indoor and outdoor master plant is proposed. Finally, an economic assessment is performed to estimate project profitability.

2. Analysis and Assessment Methodology Approach

2.1. Description of Plant Location

The manufacturing plant is allocated in a completely new building or greenfield solution. This solution uses a piece of land located in Borgaro, Torino, Italy. The location is planned inside the area indicated in Figure 1.

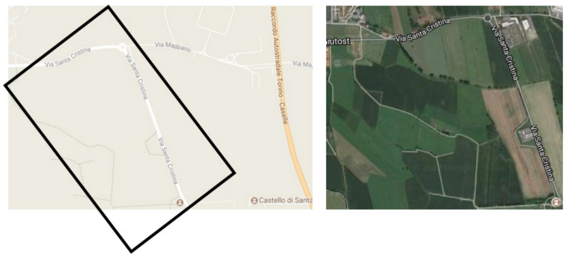

Figure 1. Study Area (source: Google Maps).

2.2. Product Description, Routings, and Production Requests

Figure 2 shows the sample of the components to manufacture. The bumpers are made up of an external body assembled with an internal component named cross beam. It allows the bumper fastening to the vehicle body through specific hooks. This bumper is for small vehicles. The cross beam and external body are assembled by a gluing machine that carries out the operation in a semi-automatic way. Additionally, the car dashboard assembly consists of some parts which are body, insert, air duct, instrument panel frame, glove compartment interior and exterior. The dashboard body and insert are welded utilizing a vibration welding machine while the other components are manually assembled. In the end, dashboards are subjected to quality inspection and then are sent to the finished product warehouse. Instead, the wheel arch is a part of the vehicle body to provide a connection with the outer body portion. It surrounds the vehicle at the top and connects with the vehicle interior. In total, there are four wheel arches in a vehicle front right, front left, rear right, and rear left.

The production routing of the bumpers starts with raw material receiving, granule loading in the press hoppers, injection molding, part unloading, cross beam gluing, final inspection, packaging and transport to the warehouse, storage in warehouse and shipping. The routing for car dashboards starts with raw material receiving, granule loading, body injection molding, insert injection molding, component injection molding, final inspection, packaging and transport to the warehouse, storage in the warehouse, and shipping. Then, the routing for Wheel arches is raw material receiving, granule loading in the press Hopper, front Wheel arch injection molding, rear Wheel arch injection molding, part unloading, final inspection, packaging and transport to the warehouse, storage in the warehouse and finally shipping process.

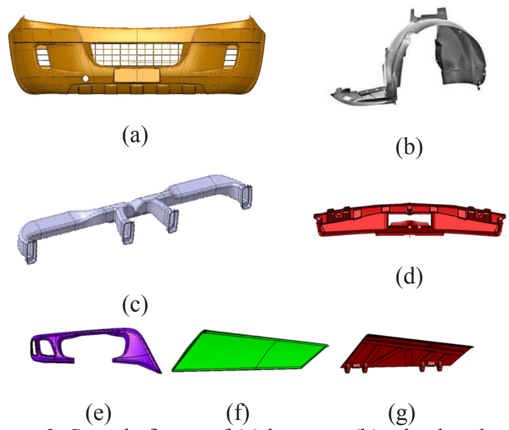

Figure 2. Sample figure of (a) bumper, (b) wheel arch, (c) air duct, (d) insert, (e) instrument panel frame, (f) glove compartment exterior and (G)glove compartment interior (Cagliano and Chiabert, 2018)

Table 1. Assigned unit loads.

Product/Component	Box size [mm]	Units/box
Finished bumper	1900×800×500	2
Finished dashboard	1800×800×700	4
Bumper body	1900×800×500	4
Bumper cross beam	1400×800×600	8
Dashboard body	1400×800×600	6
Dashboard insert	1400×800×600	10
Air duct	1000×800×800	56
Instr panel frame	1000×800×800	100
Glove comp – ext	1000×800×800	80
Glove comp – int	1000×800×800	80
Front wheel arch	1900×800×800	2
Rear wheel arch	1800×800×800	2

On an annual basis, the production request of each product is 132,000 units for bumpers, 120,000 units for car dashboards and 116,000 units for wheel arches. The operation runs 270 days a year, six days/week, three shifts for Monday - Tuesday – Wednesday – Thursday-Friday, two shifts for Saturday. Therefore, the total is 17 shifts/week. The working hour is 7.5 hour per shift. However, office staff works 8 hours per day one shift from Monday to Friday. The finished products are requested to be packed in a box with the detail mentioned in Table 1. It is also suggested that no more than two boxes can be stored on a single pallet. The unit load type for all components is a cardboard box on a wooden pallet.

2.3. Raw Materials

It is requested for the raw material storage to have a capacity to meet the requirements of a minimum of five days of production for each of the three products manufactured in the facility. For all the products, the material consists of granules of thermoplastic material available in the market in octagonal-based cartoon boxes (octa bins) placed on pallets. Each octabin contains of 1000 kg of granules and has 1000×1200×1500 (h) mm of size. The adhesive or glue is available in 25 kg drums. Each pallet carries six drums, and the total pallet sizes are 1000×1200×700 (h) mm. The raw material requirement of each component can be seen in Table 2. the abbreviation "pol." stands for polypropylene. Raw materials arrive on trucks to the receiving docks and are stocked in the storage area. The delivery of raw materials is scheduled for a maximum of three days per week.

Table 2. Raw material requirement.

Part	Raw material	Quantity/ unit [kg]
Bumper body	Talc-filled pol 30%	3.6
Bumper crs beam	Talc-filled pol 30%	0.77
Bumper +crs beam	adhesive	0.25
Dashboard body	Glass-filled pol 12%	3.19
Dashboard insert	ABS	2.06
Air duct	Glass-filled pol 12%	0.87
Instr panel frame	Glass-filled pol 12%	0.66
Glove comp ext	Glass-filled pol 12%	0.54
Glove comp int	Glass-filled pol 12%	0.53
Front wheel arch	Talc-filled pol 15%	5.6
Rear wheel arch	Talc-filled pol 15%	5.2

Therefore, it is then possible to calculate the total raw material needed per shift and the total number of pallets to store the raw material. Here, the production process is assumed to have 1% of scrap in every operation, and the calculation also considers the production request described in the previous section. The estimation of the total raw material per shift can be observed in Table 3.

Table 3. Raw Material estimation per shift and the total number of pallets needed.

Material	sum [kg/shift]	storage[pallet]
Talc-filled pol 30%	769	12
Glass-filled pol 12%	932	14
ABS	333	5
Talc-filled pol 15%	827	13
Adhesive	44	5

2.4. Machine Layout

The layout choice is determined by the number of products, production volume, the homogeneity of the product, the routings, etc. The proper choice of the machine and layout positioning is crucial to minimize the sum of manufacturing and material handling costs (Schaller, 2008). The approach that is used in this study is that, first of all, it is necessary to create a multicolumn process chart to show the production routing of each product under production. Then an activity relationship diagram needs to be created. Finally, considering the size of the machine and the available space, the machine layout can be determined.

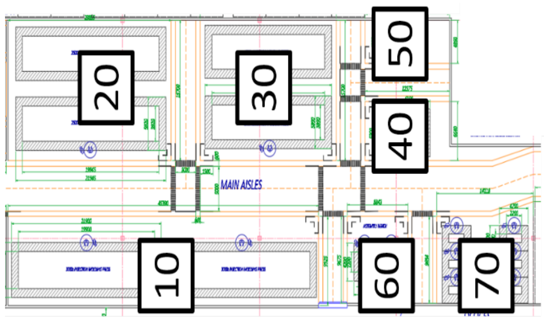

Figure 3. Machine layout position.

The multicolumn process chart indicates which workstation or machine has the most relationship with which other workstation. Figure 3 shows the solution of the machine layout proposed.

2.5. Production Scheduling

Scheduling activities could be one of the determinants in deciding the further facility design of the plant. Many scheduling techniques, optimization approaches, and evaluation to have more effective production scheduling and improvement have been proposed by many researchers (Hazaras et al., 2014, Al-Aomar, 2006, Sun et al., 2015). However, a simple continuous production scheduling is utilized as a preliminary decision of the study. Considering the production request per week, the routing, the requirement of the storage capacity of a minimum of five days, the following production schedule is possible to be applied in the production process. Even if the maintenance schedule can be adjusted to have the desired throughput (Yang et al., 2007), a simple assumption of two hours setting and maintenance schedule is set.

2.6. Machine and Workstation

The production equipment to manufacture bumpers, car dashboards, and wheel arches, together with average hourly production rate and the approximate machine cost need to be determined. The number of machines for each product can be calculated by using Equation 1. In this case, takt time is the time required to produce one unit of product. Considering 92% of efficiency and average scrap rate equal to 1%, it is possible to calculate the takt time. Then, by using the time standard, the number of machines required to produce each product is possible to calculate. Finally, the result of the number of machines required can be calculated. The calculation considers the same machine might be used to produce different products. Therefore, the computation includes the total time during the process.

$$\#machine = \frac{time\ standard}{takt\ time} = \frac{1/takt\ time}{1/time\ standard} \quad (1)$$

Based on the specification of each machine dimension, then, it is necessary to calculate the total spaces required to determine the best layout that has been mentioned in the previous section. However, it is also necessary to consider a free space to allow the workers to perform maintenance and repair action around the machine. The offset area of 1000 mm is required to be added to space. Moreover, some additional spaces to have a comfortable working environment and spacious workstation are needed. In this case, the total area is multiplied by 150% to have a spacious area.

2.7. Number of Employees

The employees consist of direct and indirect employees. Direct employees are those who work directly in the production line, and indirect employees are the one who works as officers or administration staff. For the direct employees, the number of operators for each machine needed is considering the size and the kind of job they are performing. One 3000 T injection molding press machine requires two operators. Considering the number of machines and total shifts per day in the schedule, it finally requires 12 operators. Furthermore, for 2500 T machine by considering again production schedule and because the dashboard body and rear wheel arch require two operators and the other two needs one for each, the arrangement is possible to be made one operator for one machine and two for the others. Therefore, it needs three operators for each shift. In total, nine operators are required. The gluing machine and welding machine need two operators for each, and the other remaining machines need one operator per machine. Therefore, 39 additional operators are required. Finally, a total of 60 direct employees is required.

It is, however, required to have indirect people who help the direct employee. Literature suggests having an additional 20% of direct employee that works as helpers and support functions, this includes the person who works as an administrative staff in the office (Stephens and Meyers, 2013). These employees are considered as indirect employees. Additionally, one cell supervisor per shift and warehouse workers per shift are also required. Taking into account, there are three shifts per day, and there are seven cells and the number of warehouses, the additional employee needed are 33 people. In total, there are 45 indirect employees required.

2.8. Plant Support Functions

Receiving Area functions are locating trailers at receiving docks, unloading material, opening, inspecting, counting, reporting material received, moving to the raw material warehouse (Stephens and Meyers, 2013). Receiving docks and areas must be sized to execute daily receiving functions. The approximation of size determination is calculated by the following formula.

$$\#\ of\ receiving\ docks = T \times t_T \quad (2)$$

$$Receiving\ area\ size = (S \times Q) \times t_M \quad (3)$$

Q is the quantity of incoming raw material unit loads per unit of time. In this case, we have 20 pallets/hour. T is the number of trucks per unit of time (arrival rate) that is 1 truck/hour. S is the size of the unit load of floor area which is 1000×1200 mm. t_T is the time required to unload the truck (unloading service time) which equals 45 min/truck or 0.75 hours/truck. t_M is the time required to receive and move unit loads to the raw material warehouse (moving service time) which is 2.66 hours by assuming having 4 min/pallet. The number of receiving docks is 1 and the required size is approximately 63.84 m^2. Finally, take into account the additional space for aisle and space for handling and maneuvering and also the plant condition, the final area required is about 198 m^2.

Shipping area functions are packaging finished goods for shipping, weighing, loading trailers, documentation: bills of lading (Stephens and Meyers, 2013). It is also necessary to design space for packaging, staging, aisles, offices, trailer parking and roadways. One primary constraint in determining the required area is the trailer size. The size of the trailer is commonly called FEU (fourth-feet equivalent unit) which has the dimension of 8 feet wide, 40 feet long, and 7 feet high. If it is converted into cubic meter the total volume becomes 63.431 m^3. At this point, it is necessary to calculate the number of trucks per day. The following equation is then used.

$$\#\ of\ trucks\ per\ day = \frac{volume\ product}{volume\ trailer} \tag{4}$$

However, the total volume product remains to calculate. Taking in to account all data that have been mentioned before, the number of boxes per day and the required size to store is depicted in Table 4. Therefore, the number of trucks required to ship the product is 9 trucks per day.

Table 4. Volume of product.

Production	#box/day	Vol prod/day [m^3]
Bumper	258	196.08
Car dashboard	117	117.936
Front wheel arches	113	136.8
Rear wheel arches	113	129.6
Total Volume		580.416

Apart from the area needed to store the unit loads, the area for staging and area for maneuvering for material handling is required. Considering the location and position of the land and the position of the product flow in the plant, the approximated area of the shipping activities is about 535 m^2.

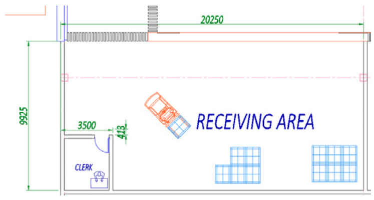

Figure 4. Receiving area.

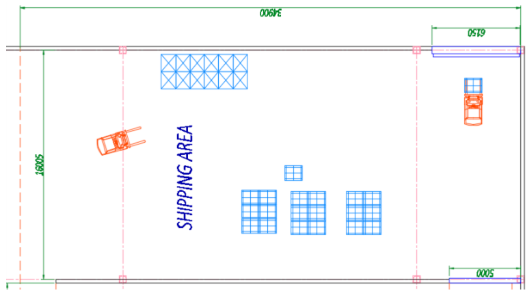

Figure 5. Shipping area.

Maintenance is a service to the company's equipment. More commonly a central maintenance area is designed to include equipment, machine overhead areas, maintenance supply, and spare parts storage areas (Stephens and Meyers, 2013). It is assumed to have approximately 150 m^2 of the total area of the maintenance room.

A tool room is made up of machines and an assembly area similar to production. The tool room size is the total of all the equipment space requirements times 200%. The assumed total area needed for the tool room is 30 m^2.

The utility room includes battery charging spaces, heating, electrical panels, air compressor, and air conditioning. These areas are kept separate from the regular traffic. Electrical panels are fenced off, heaters are kept clean, and air compressors are located in a particular construction because they are noisy. The assumed area needed is approximately 70 m^2.

2.9. Employee Facilities

Several employee facilities need to be taken into account in this section. The first employee facility is parking lots. Office parking may be different from factory parking because it can incorporate the visitor parking spaces in this area. Additionally, it might also have different parking locations for managers or guests. The wider the parking spaces are, the less door damage there is in the parking lot. It is suggested to have a minimum of 18.58 m^2 for each car (Stephens and Meyers, 2013). Considering there are 105 employees in total, the total available area for parking is about 1,950 m^2. Additional parking lots for managers and guests could be added separately.

The second facility is the employee main entrance. This is where the employees enter the plant will influence the placement of parking, the locker room, time card racks, restrooms, and cafeterias. The flow of people into a factory is from their cars into the plant via the employee entrance to their lockers and the cafeteria to wait for the start of their shifts. The employee entrance is where security, time cards, bulletin boards, and sometimes the personnel departments are located. Depending on the management's attitude and corporate requirements, employee entrance can vary from a simple doorway with a time card rack and time clock to a series of offices and gates through which to pass. The size of the employee entrance must consider individual requirements. The door could measure 1.8 m with an aisle or walkway leading into the plant.

Locker rooms give employees space to change from their street clothes to their work clothes and a place to keep their personal effects while working. Their coats, lunches, street shoes, and so forth will be kept in lockers. The size of a locker room can be initially sized by multiplying the number of employees by one m^2 per employee.

Break facilities comprise of cafeterias with serving lines, dining rooms, off-site diners for any typical plant. A table (or tables) allowing a minimum of 0.6 m width by 0.3 m length of table space per person. Chairs or seats with back support for each person likely to be eating at one time. For the individual table space for a person 0.18 m^2. However, this is adjustable as the need.

The next one is medical facilities. These facilities should give first aid and accident treatment; under special conditions, full medical care in general practice may be arranged for the workers and their families at the industrial health center. Contents of medical kit are the size and layout of the workplace, the number, and distribution of employees throughout the workplace, the nature of any hazards and the severity of the risk, location of the workplace and known occurrence of accidents or illnesses.

An office layout is the next consideration of these facilities. It needs a total of about 678 m^2 by considering the 20-25 m^2 surrounding area, aisles, stairs, and various services.

The last employee facilities are restrooms and toilets. The number of toiles must be distributed in several places as the need. The local building code may dictate how many toilets are necessary. The number of washbasins is equal to the number of toilets. The size of a restroom is 1.3 m^2 per toilet, washbasin, and entryway, and 0.83 m^2 for urinals.

2.10. Unit Loads

The main unit loads, in this case, are the unit loads for raw material, for semi-finished products and finished products. The main unit load is the pallet. In order to calculate the number of required pallets in each function department, the requirement of at least five days of minimum storage that has been mentioned in the previous section needs to be taken into account. Secondly, the requirement of no more than 2 stacks per box for finished products, total production quantity of components for one week for both semi-finished and finished products. Finally, the total pallets that are required for the production process are as mentioned in Table 5.

Table 5. Total pallets.

Item	Qty
Raw Materials	59
Finished Bumper	264
Finished Dashboard	123
Bumper body	60
Bumper cross beam	35
Dashboard body	42
Dashboard insert	50
Air duct	8
Instrument panel frame	9
Glove comp interior part	11
Glove comp exterior part	11
Front wheel arch	71
Rear wheel arch	106
Total	633

2.11. Material Handling Equipment

Equipment to move and transport the material in the plant needs to be chosen as the need. Many suggested approaches, advanced techniques, and methods for structuring and deciding the choices for outsourcing material handling could be performed (Klingenberg et al., 2010). However, the approach utilized in this study is to estimate the main equipment only. However, the main handling equipment is the forklift. To obtain the number of the forklifts needed, the different paths that will be done by the different products have to consider. The weight of the pallets is known, then considering the capacity and dimensions of the forklift, it is possible to obtain the number of the unit load/day that can be carried by one forklift. The average distance considers the journey and return. Therefore, we can get the number of forklifts needed, considering that this is a quite rough computation and useful only as a first approximation. By considering the allowed maximum speed of the forklift is 8 km/h, and the availability of each forklift per day is 8 hours, the following calculation of the number of forklifts can be calculated.

$$F = \sum_i \frac{N_i t_i}{n_i h} \tag{5}$$

where N_i is the number of unit loads that have to be moved per day of each item. n_i is the number of the unit load carried by one forklift in one trip. t_i is time to perform one trip by the forklift moving item *i*. *h* is the availability of each forklift per day. The distance travel is calculated based on the designed overall layout of the plant. As a result, the total forklift needed is approximately 8 units.

2.12. Warehouse

Space utilization and the performance optimization of warehouses are one of several aspects that need to consider in designing the storage system, and it depends on the kind of the warehouses (Derhami et al., 2019). In this case, the first storage is the raw material warehouse. After the material has received in the raw material receiving area, it must be moved and stored in the raw material warehouse. The raw material storage must have the capacity to meet the requirements of 5 days of production for each of the three products manufactured in the facility. Therefore, calculating the number of pallets in warehouse data in Table 6 were obtained.

Table 6. Number of pallets in warehouse.

Talc-filled polypropylene 30%	Glass-filled polypropylene 12%	ABS	Talc-filled polypropylene 15%	Single-component adhesive
12	15	9	17	6
Total = 159 pallets				

These total number of pallets are utilized to determine the area of the warehouse. Then, these data are then used to design the number of the desired column, horizontal and vertical dimension and the aisle dimension. Considering the amount of quantity and the moving frequency, it is decided to use the drive-through rack type. The design and placement of the raw material warehouse need to be designed in such a way by considering also the aisles. The total approximate area of the raw material warehouse, therefore, is 263 m^2.

Furthermore, it is necessary to calculate the space for storing intermediate products. As we know from the production schedule all the components are produced in different shifts and need to be stored until another component of the same product has produced before assembling takes place. Therefore, to store the intermediate products, the warehouse with the capacity to store the maximum number of intermediate components produced in a week has been designed nearby assembly line. Components will be moved and stored in unit loads, considering that no more than 2 boxes can be stored on a single pallet, placed one over the other. Wheel arches can directly be stored in the finished product warehouse as it does not have any assembling process. The maximum number of unit loads/boxes required to store into the intermediate warehouse is in Table 7.

Table 7. Max number unit loads.

Bumper body	Bumper cross beam	Dashboard body	Dashboard insert	Air duct	Inst panel frame	Glove comp int	Glove comp ext
64	69	84	0	0	6	11	14
Total = 246							

The total number of bumper body pallets to be stored in the warehouse of all the products are 64. Therefore, the number of necessary columns is 64/ (5×7) = 1.83 ~ 2 columns by considering 35 shelves in a column, 5 vertically and 7 horizontally. The total number of the bumper crossbeam, dashboard body, dashboard inserts (having the same size) pallets to be stored in the warehouse of all the products are 153. Therefore, the number of necessary columns is 153/ (4×7) = 5.5 ~ 6 columns by considering 28 shelves in a column, 4 vertically and 7 horizontally. The total number of the air duct, Instrument panel frame, glove compartment –exterior part, glove compartment– interior part (having the same size) pallets to be stored in the warehouse of all the products are 31. Therefore, the number of necessary columns is 31/ (3×7)=1.5 ~ 2 columns by considering 21 shelves in a column, 3 vertically and 7 horizontally. The type of storage chosen is the drive-through rack. The approximate total area needed for intermediate warehouse storage is 337 m^2.

The last warehouse is the warehouse for finished products. Since the final products have different sizes of the box, to estimate the size, one shelf has 1.9×0.8×0.8 meters in size, so that it is possible to accommodate any product in it. The finished product warehouse must have the capacity to hold an inventory equivalent to 3 working days for each product and will be outfitted with appropriate material handling and storage equipment. Finished products are arranged within boxes and they are shipped by trucks.

Table 8. Boxes for production.

Production	/shift	3 days	No. of Boxes
Bumper	172	1548	774 (2 bumpers/ box)
Dashboard	156	1404	351 (4 dashboard/ box)
F Whl arches	75	675	337 (2/box)
R Whl arches	75	675	337 (2/box)
			Total=1799.

The warehouse consists of racks arranged in columns and each rack has 4 shelves (i.e. 4 height layers) by having 6 rows per column. The total number of boxes to be stored in the warehouse of all the products is 1799. Considering there are 5 stacks in each rack the proposed design of the warehouse is shown in Figure 8. The total area required is 1092 m^2 approximately.

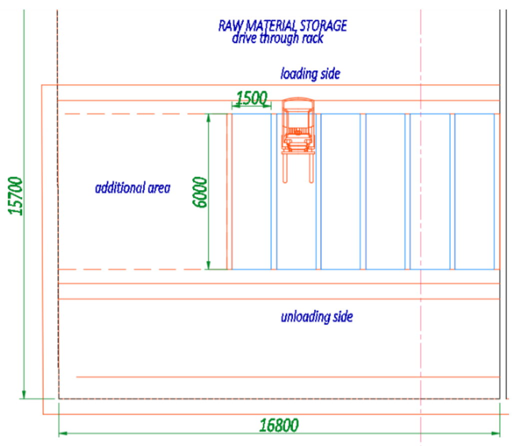

Figure 6. Raw material warehouse.

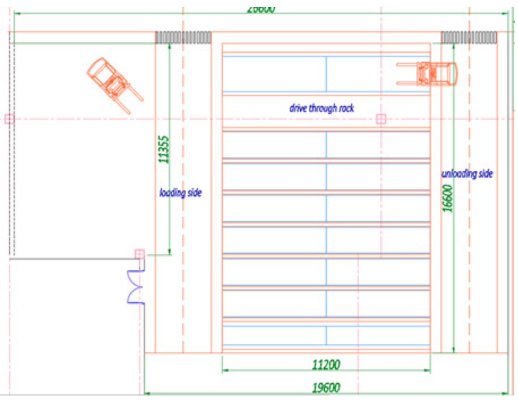

Figure 7. Intermediate warehouse.

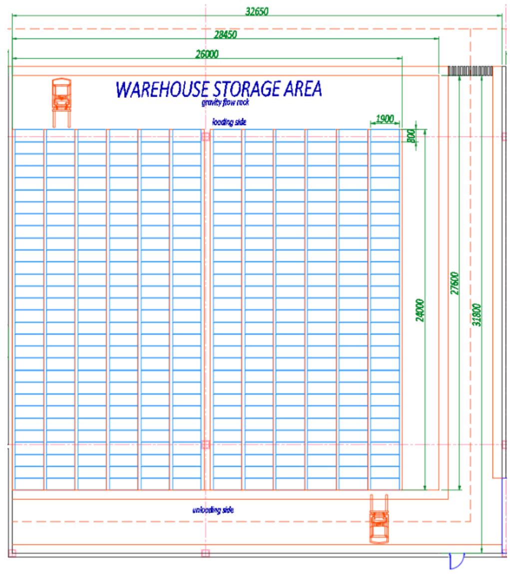

Figure 8. Finished product warehouse.

2.13. Economic Investment

After all, the economic calculation of investment unit cost needs to be performed. Table 9 shows the rough estimation of the economic investment including the main building, warehouse, material handling equipment purchase, unit load, and the machine. It is estimated that the total investment unit cost is approximately 32,105,545 €. Furthermore, Table 10 shows the operation cost for production. The total cost is about 16,614,502 €.

It is also necessary to calculate the net present value (NPV) of the industry of this solution. This value represents the sum of the present values for all of these cash-outs and cash-ins. For the calculation of NPV, it is compulsory to set the selling price. From the data in the market, the bumper prices vary in a range from 40€ to 100€, the dashboard prices vary in a range from 150€ to 250€, the wheel arch prices vary from 45€ to 85€. Here, the calculation sets three different selling prices to simulate the results of the NPV. Table 11-13 shows the results of all three cases of selling prices. The lowest selling price scenario would give the company a profit in year 7. Instead, the second pricing scenario will give the company profit in the year of 3. Then, for the last pricing scenario, the company will gain profit in the second year. However, this study needs to be further analyzed to determine the best-selling price further in the business plan of the company.

3. Discussions

Industrial facility design is highly dependent on the characteristic of the masterplan layout design (Pòvoa, 2002). Putting all together, it is possible to design the indoor master plan and outdoor master plan layout. However, some other considerations need to be taken into accounts, such as the building structure the positioning of each department, aisles, pedestrian path, forklift direction, industrial doors, emergency exit doors, and maneuvering area for material handling equipment. Therefore, the calculated area might be slightly different from the proposed layout due to the mentioned consideration.

The indoor layout masterplan, as it is depicted in Figure 10, shows the complete proposed layout for the plant. As it has been mentioned in the introduction, the hatched area is the location of another production plant which is not included in this study. Starting from the receiving area at the left side of the plant, the raw material is docked, checked and then moved to the raw material warehouse. The required machine to produce the component is then located next to the raw material warehouse for the sake of the material moving efficiency. The location of the machine is decided based on the most appropriate layout that has been discussed in the section machine layout. Practically, due to the different sizes of the required machine and the required routings, some changes are needed concerning the building characteristic, especially the presence of pillars. Here, the material moving efficiency is essential to be considered. However, it is possible to have an improvement in the further assessment of the efficiency in the material handling activity with the mathematical formulation (Fu et al., 1997), which is not performed in this stage of the study. Then, the intermediate warehouse is located on the right side of the main production area, followed by the finished product warehouse. However, the type of storing technique for the warehouse either raw material warehouse, intermediate warehouse and final product warehouse is extremely crucial. It will affect so much the required area and the final cost of investment. Finally, the shipping area could be placed on the very right side of the plant. Therefore, the flow of the production cycle is from the left side of the plant to the right side of the plant with respect to the proposed area.

In addition, the placement of the plant support function and employee facilities will follow. The utility room, battery charging area, tool and maintenance room, toilets, must be connected with aisles effectively. The main entrance must be placed in the accessible area and in this case, is in the lower part of the proposed layout, nearby the cafeteria, hall, medial room and offices and also locker room. This layout allows the direction and the separation of the direct and indirect employees to go to their workplaces. The emergency exit must be placed in several places by considering the level of emergency of the plant. There are several approaches that can be implemented in the determination of a facility sitting for fire and explosion scenarios (Jung et al., 2011). However, simple fixed distance measurement is implemented in this study by considering the distance of the potentially explosive machine to the location of the emergency exit.

Instead, Figure 9 shows the proposed outdoor facilities of the plant. With respect to the location being studied, all the entrance and exit for the car and trucks are decided in towards Santa Cristina Streets considering the size of the road. It is suggested to have different gates between the main gate and the gate for trucks. The main gate is the gate for employees and guests. After the security point, the employees park their car in front of the plant. The main entrance is exactly next to the parking area. The parking area needs to consider also the necessary space and the special places for disable. The separated parking area is also available for guests and some important people next to the main entrance. Service station consisting of the gas source, the water source is placed separately from the main building. The flow of the incoming and outgoing material and products is separated from the main gate. The truck gate 1 indicates the entrance of the trailer for incoming raw material. It directs to the receiving area where the maneuvering space is also available at this point. The direction employs one way or one direction flow so that the trucks enter from truck gate 1 and exit by truck gate 2. On the right side of the plant, there is also a maneuvering area where the shipping area is located. The area is wide enough for the trailer to park the truck. The proposed area also considers the possibility for the plant to expand the company. The open area, in this case, can be used as the expansion area for the company in the future. The outer part of the company area is separated by fences and the distance of the outer fences needs to respect the regulation of the minimum distance from the main road.

4. Conclusion

Several points can be derived from the analysis and the proposed assessment method of this study. The design process of the study follows several steps. First of all, the definition of the input data, definition, quantity of required equipment needs to be determined. Then, it is essential to have an idea about the dimensionless plant layout diagrams to have first knowledge of the plan. The machine selection based on independent research, literature research or experiment needs to be conducted. The design of the workstation also needs to consider the principal of workstation ergonomics. From the data obtained in the first step of the study, the decision of the material handling equipment needs to be considered. After that, it is possible to get o the plant layout conventional design, through sizing of production centers, aisles, support functions' space requirements, building frame size definition, and others. After finishing the plant for indoor layout, an outdoor facility plan design is the next step to be conducted. Finally, the investment evaluation via cash flow analysis needs to be performed. The main contribution of this paper relies on the clear process of initial assessment in the case of automotive sector with some examples of data which was described and proposed. However, the proposed data and calculation is the estimation of all. In practice and further study, several points could be eliminated or even be added. This study is one part of the feasibility design of the requested work. The next activity is to determine another part of the study which is the production of other automotive parts that are indicated and allocated for the hatched area of the indoor masterplan.

5. Acknowledgments

Gratitude and appreciation are expressed to Prof Anna Corinna Cagliano and Politecnico di Torino for complete support and advisor for this project.

Table 9. Investment unit cost.

	unit	single price	quantity	total cost[€]
steel structure	€/m^2	950	16200	15390000
building systems	€/m^2	360	16200	5832000
industrial door	€each	9300	4	37200
emergency exit door	€each	2800	6	16800
protection grids	€/m	100	8	800
receiving/shipping dock	€each	3500	2	7000
warehouse				
drive-in racks	€unit space	70	63.84	4468.8
gravity flow racks	€unit space	320	547.2	175104
material handling equipment				
Forklift (lifting height 3-6m)	€each	31200	8	249600
drum lift and tip trolley	€each	1234	3	3702
hand pallet trucks	€each	800	4	3200
unit load				
wooden pallet	€/unit	689	30	20670
machine				
3000t injection molding press	€/unit	2100000	2	4200000
2500t injection molding press	€/unit	1800000	2	3600000
1000t injection molding press	€/unit	850000	2	1700000
gluing machine	€/unit	300000	1	300000
welding machine	€/unit	415000	1	415000
assembly bench	€/unit	30000	2	60000
test bench	€/unit	15000	6	90000

Table 10. Operation cost

raw material	total		total cost [€]
Talc-filled polypropylene 30%	34.605 t	1330 €/t	46024
Glass-filled polypropylene 12%	41.940 t	1380 €/t	57877
ABS	14.985 t	2020 €/t	30269
Talc-filled polypropylene 15%	37.215 t	1330 €/t	49496
Single-component adhesive	1980 kg	5 €/kg	9900
# direct labor	€/h	h/year	total cost
60	38	6075	13,851,000
manufacturing O/H head			total cost
utilities, plant management	3 €/h	97200 h	291,600
facilities management	4.3 €/m^2	54936 m^2	236,225
selling, general and administrative	total cost		
maintenance	642,111		
selling and administrative	1,400,000		

Table 11. Case 1 selling price and NPV.

production revenue	€/unit	production	total cost (€)
bumper	40	132,000	5,280,000
car dashboard	150	120,000	18,000,000
wheel arch	45	116,000	5,220,000
			23,280,000

	year 0	year 1	year 2	year 3	year 4	year 5	year 6	year 7
CF	-32,105,545	6,665,498	6,665,498	6,665,498	6,665,498	6,665,498	6,665,498	6,665,498
NPV	-32,105,545	-25,876,108	-20,054,204	-14,613,172	-9,528,095	-4,775,687	-334,184	2,998,565

Table 12. Case Vselling price and NPV.

production revenue	€/unit	production	total cost (€)
bumper	75	132,000	9,900,000
car dashboard	200	120,000	24,000,000
wheel arch	65	116,000	7,540,000
			33,900,000

	year 0	year 1	year 2	year 3	year 4	year 5	year 6	year 7
CF	-32,105,545	17,285,498	17,285,498	17,285,498	17,285,498	17,285,498	17,285,498	17,285,498
NPV	-32,105,545	-15,950,874	-853,051	13,257,065	26,444,088	38,768,410	50,286,467	58,929,216

Table 13. Case 3 selling price and NPV.

production revenue	€/unit	production	total cost (€)
bumper	100	132,000	13,200,000
car dashboard	250	120,000	30,000,000
wheel arch	85	116,000	9,860,000
			43,200,000

	year 0	year 1	year 2	year 3	year 4	year 5	year 6	year 7
CF	-3,2105,545	26,585,498	26,585,498	26,585,498	26,585,498	26,585,498	26,585,498	26,585,498
NPV	-32,105,545	-7,259,285	15,961,518	37,663,204	57,945,153	76,900,246	94,615,286	107,908,035

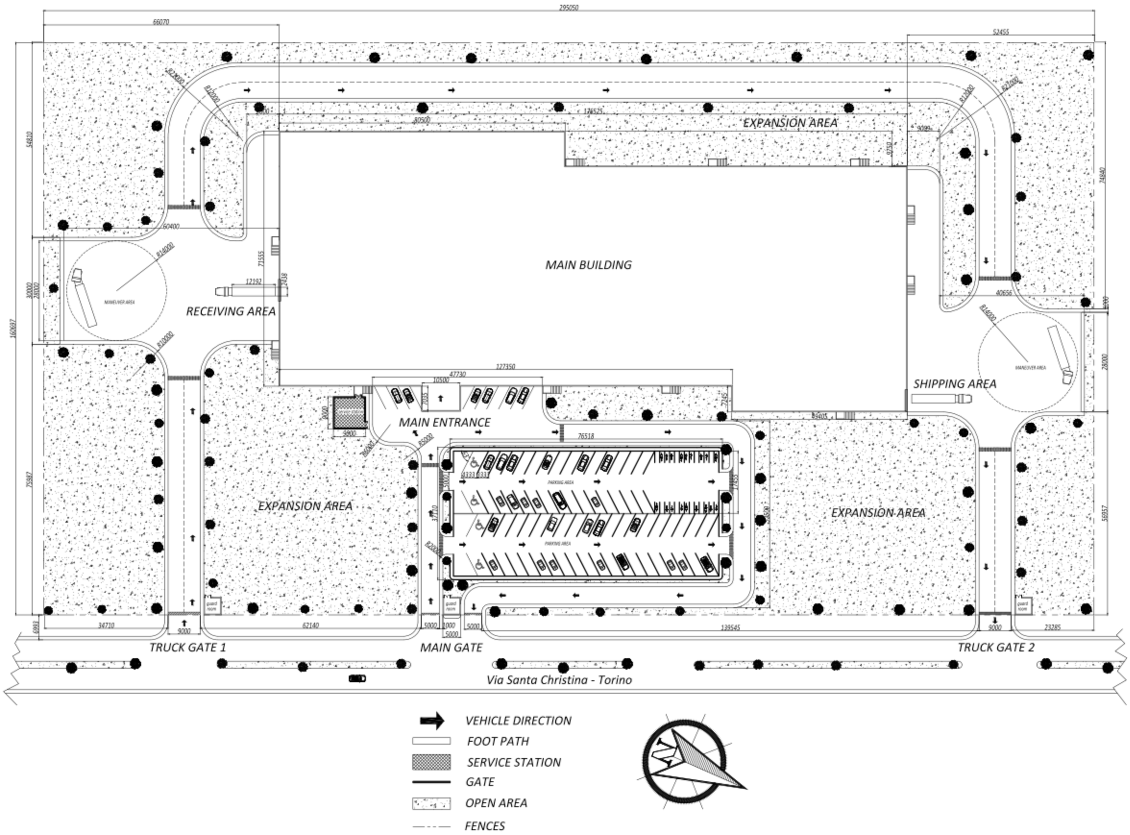

Figure 9. Outdoor layout master plan.

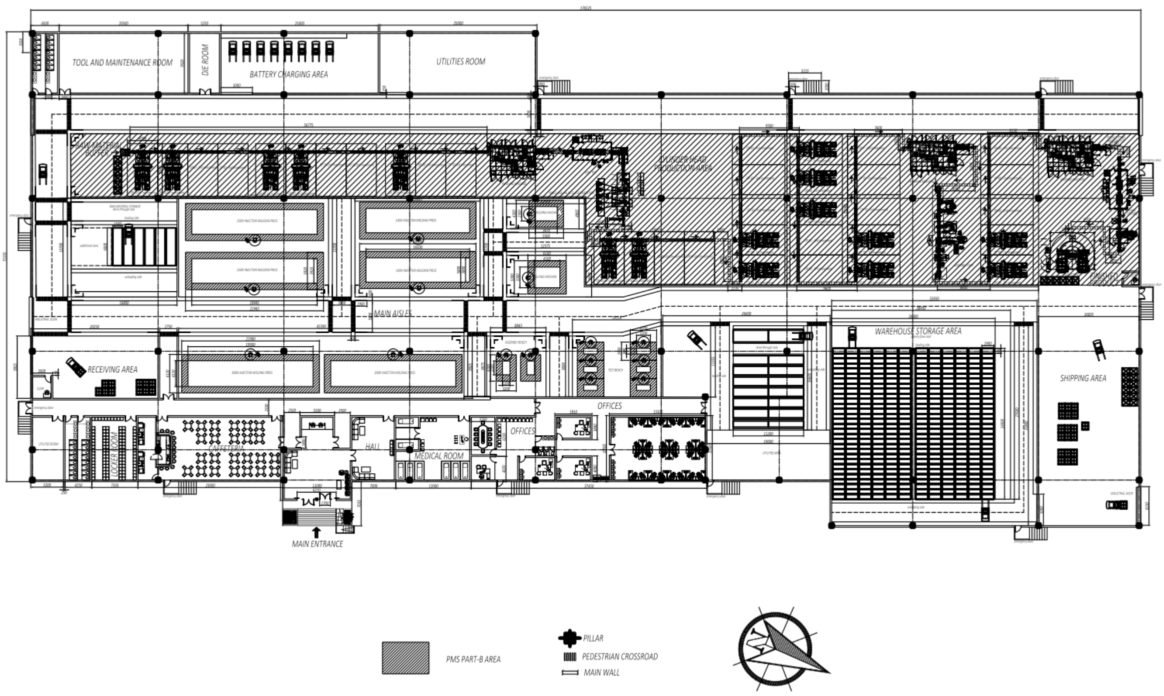

Figure 10. Indoor layout master plan.

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