Facility layout problem with auxiliary systems for energy efficiency

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Abstract

In the facility layout design, few research explicitly considers the energy costs even though increasing attention is placed on the energy consumption related to auxiliary systems such as electrical supply, process heat, refrigeration, and compressed air. The approaches to solve the Facility Layout Problem (FLP) traditionally only consider the costs related to the material flows, while the auxiliary systems are designed after the definition of the facilities placement. However, the arrangement of departments/machines influences the investment cost, associated with the installation of the distribution system of auxiliary systems, and their operating costs which in several cases represent a relevant part of the overall costs. Therefore, in light of an energy-efficient solution, the facility layout design should be based not only on the material flows but also on the auxiliary systems. The objective of this study is to present a novel approach to FLP that jointly allows the optimization of the department's arrangement and machines by considering both investment and operating costs related to the electrical service jointly to material flows. A mathematical model and a solution algorithm to address the positioning of the electrical panel board and the selection of electrical cable sections are presented. The application of this new method enables to achieve of an overall total cost minimization with consistent savings compared to the traditional FLP approach.

Keywords: Facility Layout Problem, Energy Savings, Auxiliary Systems.

1. Introduction

The traditional approaches for solving the Facility Layout Problem (FLP) only consider the costs related to the material flows. The problem consists in the position of facilities/machines in a specific layout in order to minimize the distance among them in function of the productive interaction (i.e. the machines with a high material flow among them will be placed near). In general, the auxiliary systems (i.e. electrical service, water service, …) are designed after the definition of the facilities placement. This leads to design the auxiliary system by considering the placement of the machines in the plant as a constraint and, in general, this approach leads to an increasing of installation costs and operating costs. In the specific, we consider the sizing of the electrical service and the impact of the installation and operating costs. In the facility layout design, few research explicitly considers the energy costs even though an increasing attention is placed on the energy consumption related to auxiliary systems such as electrical supply, process heat and refrigeration, compressed air. These systems have an important impact on the energy consumption of the production systems and their correct design and management can lead to important energy saving (Zanoni et al., 2018). The focus of this contribution is to introduce a new formulation of the FLP in order to optimize the facilities/machines position by considering at the same time the sizing of the electrical service. In particular, we develop a new heuristic procedure, simple to apply in a real industrial context, in order to solve the formulation of FLP with the sizing of the electrical service.

Panteado and Ciric (1996) presented an approach to process layout design in a chemical plant integrating safety and economics aspects. In particular, the cost of a layout is a function of piping cost, land cost, financial risk, and protection devices cost. They defined a mixed-integer nonlinear optimization problem (MINLP) that identifies attractive layouts minimizing overall costs by determining the coordinates of each unit, the total piping length, the amount of land occupied, and the safety devices that have to be installed at each unit. In this work it is considered the piping design, but not the sizing of other auxiliary services as for example the electrical service.

Drira et al. (2007) presented a survey about the Facility Layout Problem by considering the manufacturing system features, static/dynamic considerations, continual/discrete representation, problem formulation, and resolution approach. However, in the objective function definition the auxiliary systems sizing is not considered.

Zhao et al. (2017) proposed a new FLP methodology based on surplus rectangle fill algorithm and genetic algorithms that considers the facilities as rectangular shapes. In the objective function, they consider land cost and piping cost. In particular, the Authors conclude that total cost is reduced not only by changing the relative positions of facilities, but also by changing the aspect ratios of key facilities which have great influence on the whole occupied area. They apply their analysis to a refinery plant and consider on the layout design only the piping sizing.

Wang et al. (2018) determined the locations of facilities in a large scale industrial plant considering multi floor structure. They apply a surplus rectangle fill algorithm to a real refinery with 217 facilities and 224 connections of material flows. In their model by an auxiliary system design point of view, they consider the sizing of the pipeline and pump room in the cost function, but they don't consider the electrical service design and costs. Also, they consider in the cost function the number of floors and the land costs. The sensitivity analysis show that the number of floors is the most critical variable in terms of investment costs, energy consumption and land resource.

O'Neill et al. (2020) proposed mixed-integer linear programming (MILP) models for the 2-dimensional and 3-dimensional problems by providing a formulation of the problem that considers, not only the standard layout problem, but also a modular block layout to allow modular construction and transportation of the plant. The objective is to minimize the rectilinear distance of the connections between the different parts of the layout without considering the effect of the auxiliary systems.

Perez-Gosende et al. (2021) published an extended literature review about the Facility Layout Planning. In particular, 232 papers have been classified considering the type of problem, approach, planning stage and characteristics of production facilities by configuring the material handling system and methods to generate and assess layout alternatives. However, the sizing of the auxiliary services is not considered in the review.

Iqbal and Al-Ghamdi (2018) present an energy-saving method by assigning manufacturing processes to various machines and by considering the transport energy consumption among them. In particular, the Authors simplify the transport energy consumption as a function dependent on the part's weight. They do not consider the losses derived from the auxiliary systems and the sizing of the electrical cables and the related costs.

Lamba et al. (2020) formulated a FLP as a mixed-integer non-linear model by considering in the optimization the energy consumption of the automated guided vehicles (AGV), the material handling and the rearrangement cost. In this work the Authors consider only the energy consumption of the transportation vehicles.

Similarly, Zhang et al. (2022) proposed an energy-efficient facility layout (EFL) in a manufacturing workshop environment by considering the energy consumption of the AGVs. They proposed a multi-objective particle swarm optimization-based solution method but in the definition of the energy consumption the Authors didn't take into account the energy losses derived from the auxiliary systems.

Moreover, a recently fast-growing research stream, i.e. layout design of wind farms, already integrated electrical sizing in the overall optimization, an example is the work of Lumbreras and Ramos (2013) defined a MIP model in order to design the electrical layout of an off-shore wind farm. In particular, the model minimizes the investment and production costs due to equipment failure and losses, by defining the position and the layout of the transformers. However, the Authors do not consider explicitly the sizing of the electrical cables and the related costs. Recently Cerveira et al. (2021) proposed an integer linear programming model to design wind farms' cable layout with several turbines. The proposed model obtains the optimal solution considering different cable types, infrastructure costs, and energy losses.

From the Literature review appears that some of the research has focused the attention of the layout design explicitly considering the technical aspects of auxiliary systems (e.g. the piping sizing and its costs) but no contribution, to the best knowledge of the authors, has fully considered the energy impacts of the auxiliary systems and its effect on the decision of layout design.

The objective of this paper is to bridge the gap summarized by the above Literature review, and present a new formulation of FLP that takes into account the sizing of the electrical service considering installation and operating costs, where installation costs consist of the cables for the electrical supply of different machines which may differ due to different layout alternative while operating costs comprises traditional layout costs, i.e. material flow, and electrical costs due to losses in the cables that supply each machine. The novelty of the present work is:

- a new formulation of FLP that considers the sizing of the electrical service considering installation and operating costs;
- the related heuristic procedure in order to solve it.

The paper is organized as follows: Section 2 defines the problem to be solved and its main assumptions. In Section 3, the methodology and formulation are shown. Section 4 offers a numerical example and, finally, Section 5 focuses on hints for discussion and conclusions.

2. Problem definition

Facility layout problems (FLP) deal with selecting the location of facilities (e.g., machines, departments) within a plant in order to minimize total weighted distances, where weights are representative of the material flow among them. The solution to this problem gives assignment of each facility to each location such that the total cost is minimized (S.S. Heragu, 1997). In the industrial facility layout location, in addition to the minimization of the weighted distances, it is necessary to consider the sizing of the auxiliary systems.

A service (or auxiliary) plant is an organic unit, inserted in the production structure (of goods or services), which carries out within it a complete cycle of treatment of a service such as providing water, thermal energy and electricity. The main functions performed by the auxiliary systems are for example the production and/or distribution of mechanical, electrical and thermal energy, or the supply, transport and unloading of solid materials or fluids.

Service facilities may also concern the creation of environmental conditions suitable for the production and storage of goods and the well-being of workers or alternatively the creation of hygiene and safety conditions in the workplace and outdoors.

The main types of auxiliary systems are:

- electrical supply;
- compressed air supply;
- cooling water supply;
- thermal supply (hot air and/or saturated and superheated steam…);

In the present work, we consider in the FLP the sizing and costing of the electrical supply in a specific plant area; in particular, we consider the positioning of the electrical panel board and the sizing of the electrical cables from the electrical panel board to the facilities/machines in low voltage of the plant area considered and the calculation of the related costs.

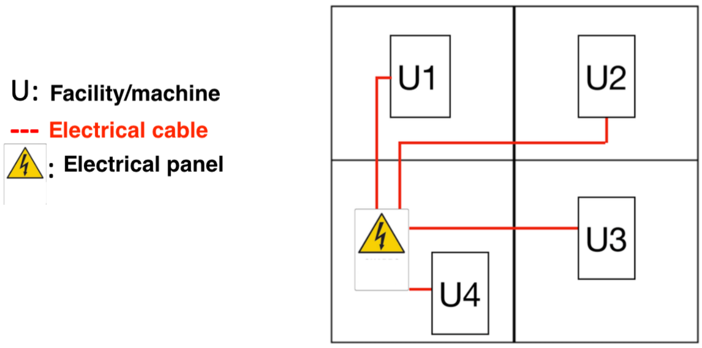


Figure 1: FLP with sizing of the electrical service

In figure 1, it is shown an example of a plant area with four locations and four machines. The electrical panel board is positioned in the same location of machine #4 and there are four electrical cables from the electrical panel board to the four machines. After the positioning of the electrical panel board and given the length of the electrical cables among the electrical panel board and the facilities/machines, it is possible to evaluate the voltage drop and the cost of the electrical system by considering the installation costs and the operating costs.

Following we report the procedure used in order to evaluate the effect of the voltage drop and the calculation of the electrical system sizing; the procedure have to be executed for every electrical cable present in the plant given the position of a specific electrical panel board.

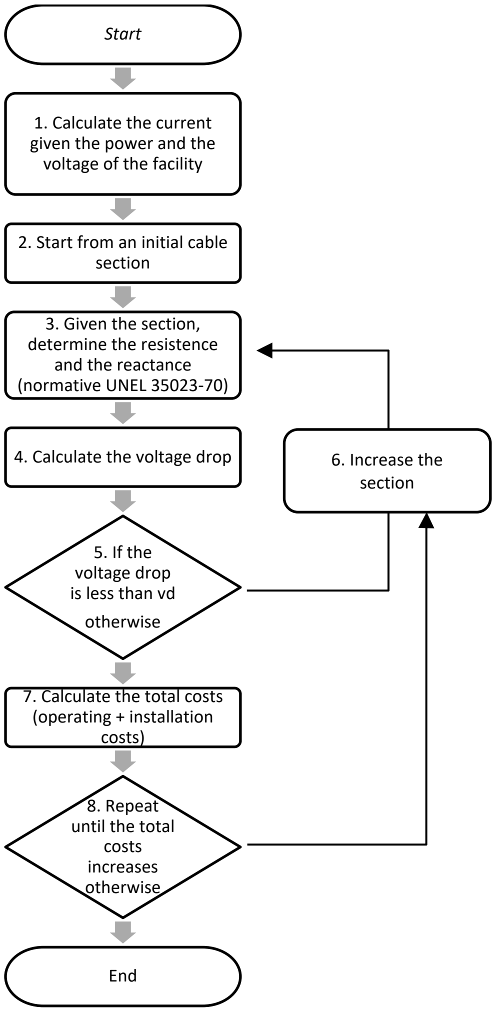


Figure 2: Procedure for the calculation of the electrical service costs.

In particular, as shown in the previous process flow, if the voltage drop is greater than *vd* (the limit of the voltage drop), it is necessary to increase the section of the electrical cable until the constraint is satisfied so as to correctly supply the electrical energy to the machine.

After the determination of the electrical cable section, it is possible to calculate the installation costs and the operating costs of the entire electrical system. The installation costs depend on the price and the length of the electrical cable; in particular, the price increases when the section increases. From the other hand, the operating costs mainly depend on:

- the characteristics of the electrical cable (length and resistance),
- operating parameters of the facility (power required profile and operating time)
- costs parameters (the energy cost and the actualization value).

The specific formulas are presented in the model description section.

It is important to consider, in the definition of the electrical service costs that exists a trade-off between the installation costs and the operating costs in function of the electrical cable section (by considering constant the other parameters). In the following figure is represented the typical behavior of the two costs and the related total cost in function of the electrical cable section

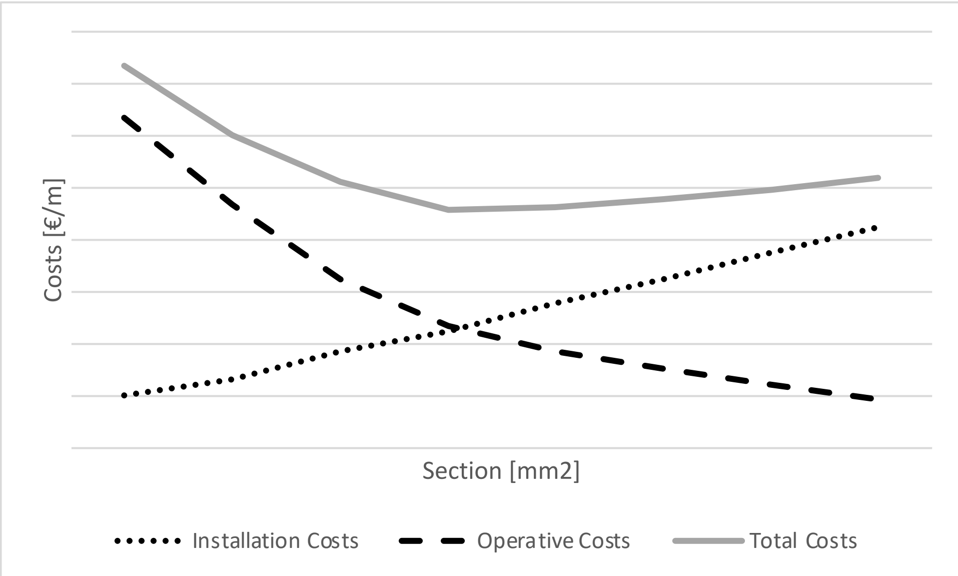


Figure 3: Trade-off between the operating and installation costs for different electrical cable section.

In figure 3, it is represented the total costs (expressed in euros per meter) given by the sum of the operating costs and the installation costs while in the x-axis it is shown the electrical cable section (expressed in mm^2); the first one decreases with the increases of the section while the second increases. It is possible to recognize the optimal value of the section that minimizes the total costs.

By considering that the sizing and cost of the electrical service depend on the length of the electrical cables (i.e. the distance among the electrical panel board and the facilities/machines of the plant), it is important to introduce this evaluation in the FLP. In the following section we show a FLP problem variant that jointly considers facilities/machines and electrical panel board positioning integrating in the objective function the electrical service costs. The model is based on the quadratic assignment problem (QAP) formulation.

3. Model description

In order to optimize the electrical cable sizing, an heuristic can be implemented: the flow chart of the heuristic proposed is reported in Figure 4.

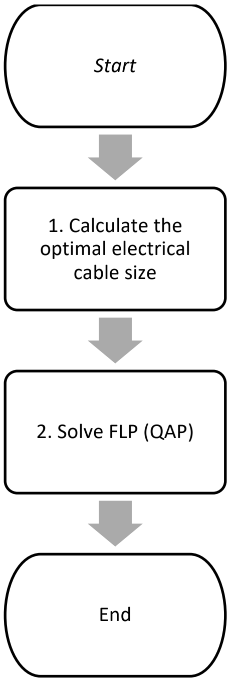


Figure 4: Flow chart of the heuristic

The problem considered is divided in two parts. The first part is related to the determination of the optimal size of the electrical cable, while, in the second part, the FPL that considers the positioning of the electrical panel board in the plant is solved.

In order to size the electrical cable from the electrical panel board to the facility *i*, it is necessary to define the cable size:

1. that minimize the cost per distance unit ce_i;
2. that satisfy the voltage drop constraint.

Thus, it is possible to write the following equations:

$$ce_i = pr_i + 3R_i I_i^2 T_{fi} PVAe \qquad i = 1, \ldots, n \quad (1)$$

$$\frac{|\Delta V_i|}{V_i} = \frac{\sqrt{3} d_{hk} I_i (R_i \cos\varphi_i + X_i \sin\varphi_i)}{V_i} \le vd \qquad h, k = 1, \ldots, n \quad (2)$$

$$PVA = \frac{(1+o)^t - 1}{o(1+o)^t} \quad (3)$$

where:

- ce_i is the electrical cable cost per distance unit of the facility *i*;
- pr_i is the price of the electrical cable [€/m];
- *vd* is the limit of the voltage drop [%];
- R_i is the resistance of the electrical cable from the panel *p* and the facility *i* [Ω/m];
- X_i is the reactance of the electrical cable from the panel *p* to the facility *i* [Ω/m];
- I_i is the current in the electrical cable that depends on the power and voltage of the facility *i*;

- Tf_i is the average operating time of the facility *i* in one year;
- *e* is the energy cost [€/kWh];
- V_i is the voltage of power supply to facility *i*;
- $cos\varphi_i$ is power factor correction for the facility *i*;
- *PVA(o, t)* is the present value of an annuity, i.e the current value of future payments from an annuity, given a specified interest rate;
- *o* is the interest rate;
- *t* is the life expressed in number of years of the electrical cable.

Constraint (2) assures that the voltage drop is lower than *vd*. The reactance X_i and the resistance R_i depend on the size of the electrical cable as shown in table 1 as defined in the legislation UNEL 35023-70. In the following table is also reported the price of the electrical cable in function of the standard cable section.

Section [mm^2]	Resistance *R* [Ω/km]	Reactance *X* [Ω/km]	Price [€/km]
1	22.5	0.125	924
1.5	15.1	0.118	1300
2.5	9.08	0.109	1891
4	5.68	0.101	2652
6	3.78	0.0955	4587
10	2.27	0.0861	6780
16	1.43	0.0817	10207
25	0.907	0.0813	14140
35	0.654	0.0783	20091
50	0.483	0.0779	26562
70	0.334	0.0751	37339
95	0.241	0.0762	44866
120	0.191	0.0740	55762
150	0.157	0.0745	65000
185	0.125	0.0742	75000
240	0.0966	0.0752	85000

Table 1: Reactance X and the resistance R for electrical cable section (UNEL 35023-70).

Thus, in the first step of the heuristic, starting from the initial electrical cable size, the procedure increases the size of the electrical cable until the cost per distance unit ce_i decreases.

In figure 5, as an example, it is reported the graph that shows the behavior of ce_i with respect to the section value.

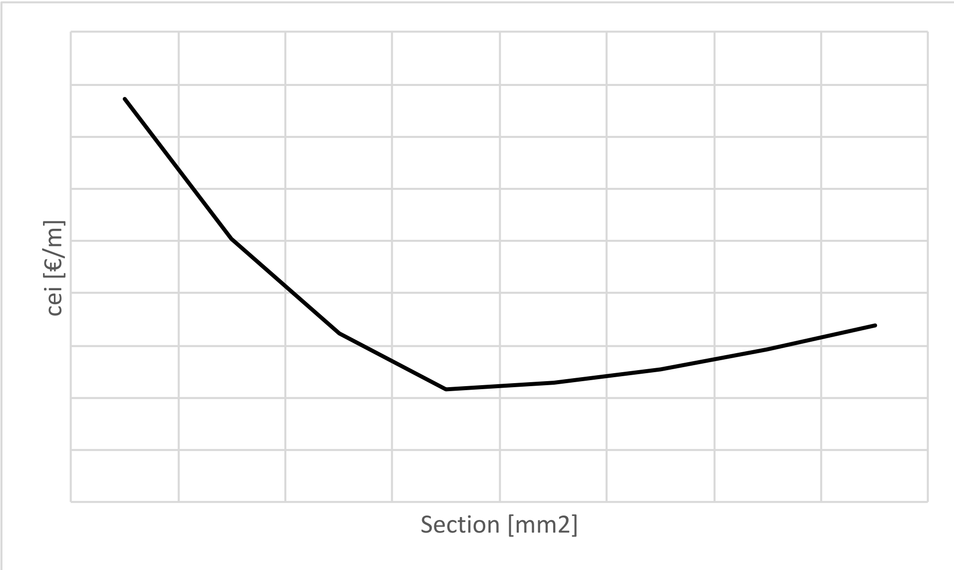


Figure 5: Behavior of ce_i with respect to the section

After the definition of the cost per distance unit ce_i, for each facility which satisfy the voltage drop, it is possible to use these values in order to solve the FLP by exploiting the quadratic assignment problem (QAP) formulation.

Koopmans and Beckmann (1957) introduced the quadratic assignment problem (QAP) as a mathematical model for the position of a set of facilities to a set of locations, where the cost is a function of the distance and flow among the facilities, plus costs associated with the placing of facilities at a certain location. The objective is to assign each facility to a location such that the total cost is minimized. In particular, given f_{ij} the flow between the facility i and facility j, d_{kl} the distance between the location k and location l, and b_{ik} the cost of placing facility i at location k, $N = \{1, 2,\ldots,n\}$ is the number of facilities and locations considered, the QAP can be formulated as follows:

$$\min_{\phi \epsilon S_n} \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij} d_{\phi(i)\phi(j)} + \sum_{i=1}^{n} b_{i\phi(i)} \qquad (4)$$

where S_n is the set of all permutations ϕ: $N \rightarrow N$. Each individual product $f_{ij} d_{\phi(i)\phi(j)}$ is the cost of assigning facility i to location $\phi\ (i)$ and facility j to location $\phi(j)$.

The QAP is NP-hard (as proved by Sahni and Gonzalez, 1976) and no exact algorithm can solve problems of size n > 20 in reasonable computational time.

The formulation (4) can be defined as the following integer program with quadratic objective function (hence the name Quadratic Assignment Problem).

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} c_{ijkl} x_{ik} x_{jl} + \sum_{i,j=1}^{n} b_{ij} x_{ij} \qquad (5)$$

s.t.

$$\sum_{i=1}^{n} x_{ij} = 1, \qquad j = 1, \ldots, n \ (6)$$

$$\sum_{j=1}^{n} x_{ij} = 1, \qquad i = 1, \dots, n \quad (7)$$

$$x_{ij} \in \{0,1\}, \qquad i, j = 1, \dots, n \quad (8)$$

In particular, c_{ijkl} is the product of f_{ij}, d_{kl} for all i, j, k and l with $i \neq j$ and $k \neq l$ and PVA that is the present value of an annuity, i.e the current value of future payments from an annuity, given a specified interest rate, while generic x_{ij} is the assignment variable. Whenever we write $(x_{ij}) \in X_n$, it will be implied that the x_{ij} satisfy the constraints (6), (7) and (8).

In the case of the problem taken into account, we modify the objective function in order to consider the costs and the constraints derived from the position of the electrical panel board and the size of the electrical cables. In particular, the size of the electrical cables depends on the distance between the position of the electrical panel board and the positions of the facilities. The objective is to assign the electrical panel board to a location such that the total cost is minimized. In the objective function (9) it is possible to recognize the first element regarding the classical cost of the QAP and the second element regarding the cost of the electrical cable depending on the distance between the location of the electrical panel board and the location of the facilities.

Starting from the (5), the new formulation can be defined as following:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} c_{ijkl} x_{ik} x_{jl} + \sum_{i,h,k=1}^{n} ce_i d_{hk} x_{ik} z_h \quad (9)$$

s.t.

$$x_{ij} \in X_n \quad (10)$$

$$\sum_{h=1}^{n} z_h = 1, \quad (11)$$

$$z_h \in \{0,1\}, \qquad h = 1, \dots, n \quad (12)$$

where:

- z_h is the assignment variable of the electrical panel board to the location h;
- d_{hk} is the distance between the location h of the electrical panel board and the location k of the facility i;

In the next section, we apply the heuristic proposed to a specific case in order to analyze the behavior of the model and the results.

4. Results

In this section, we apply the model presented to a simple case, in order to show the effect of the positioning of the electrical panel board. In particular, we show that the operating and installation costs of the electrical service change the solution of the classical FPL problem based only on the costs related to the distance and flow among the facilities/machines. The non-linear problem presented in the previous section is solved using LINGO®.

The base scenario presented consists of three locations and three CNC machines, with the electrical parameters reported in the following table, and one electrical panel board. The small size of the problem instance defined doesn't change the conclusions about the model application, but, at the same time, permits to check the consistence of the solution presented.

Machine	Power *P* [W]	Voltage *V* [v]	Cosφ	Current *I* [A]	Average operating time *Tf* [h/year]	Initial section [mm^2]
1	25000	400	0.9	40	3600	14
2	15000	400	0.9	24	3600	8
3	30000	400	0.9	48	3600	16

Table 2: Machines electrical parameters.

This section will be optimized by the heuristic in order to satisfy the constraint (11) and the minimization of the electrical cable cost.

In order to solve the problem, in the next table are reported the other parameters used.

Parameter	Symbol	Value	Unit
Energy cost	e	0.2	€/kWh
Actualization value	PVA	12.46	-
Interest rate	o	5	%
Electrical cable life	t	20	years
Voltage drop limit	vd	5	%

Table 3: Instance parameters.

In the following figure, it is reported the flow matrix and the distance matrix used typically for the FLP and the distance matrix (named electrical distance matrix) used for the positioning of the electrical panel board. The flow matrix represents the actualized costs [€/m] for the material movement among the facilities/machines (manual movement considered) while the two distance matrices are expressed in meter. In the specific, the electrical distance matrix differs from the distance matrix only for the diagonal values. In fact, it is assumed that if the electrical panel board is positioned in the same location of one machine, the distance is not zero but 0.5 m.

Flow	A	B	C
A	0	10	5
B	10	0	8
C	5	8	0

Distance	A	B	C
A	0	3	4
B	3	0	2
C	4	2	0

Electrical Distance	A	B	C
A	0.5	3	4
B	3	0.5	2
C	4	2	0.5

Figure 6: Actualized flow cost, distance and electrical distance matrixes.

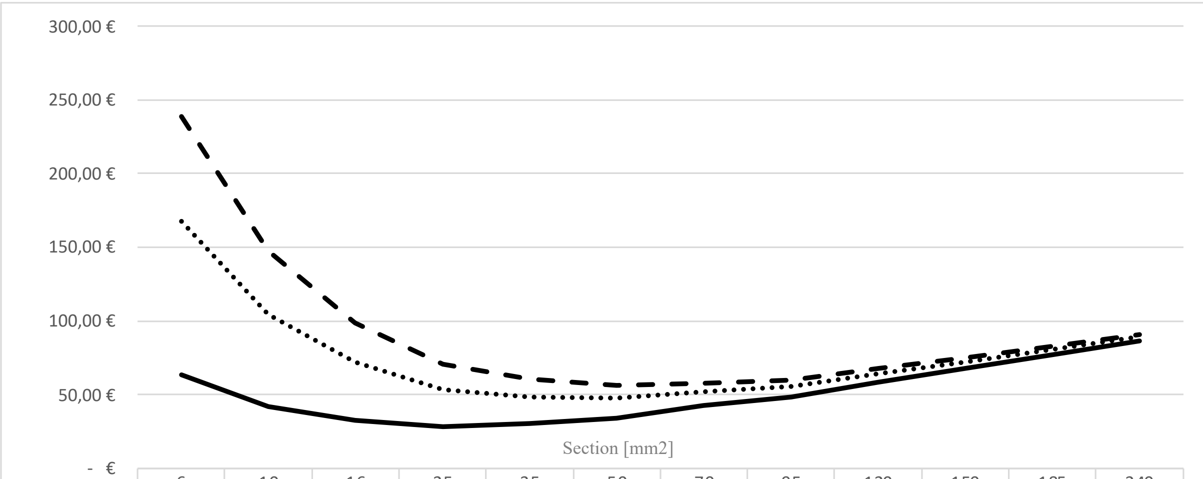
By solving the FLP without considering the positioning of the electrical panel board and the related cost, the best solution in term of actualized flow cost is 64 € with the position of the machine 1 in location C, the machine 2 in location B and the machine 3 in location A, named in the following of the paper "flow solution". Otherwise, by considering the position of the electrical panel board and the electrical service cost in the total cost function, the solution changes. In particular, the solution will be machine 1 in location C, machine 2 in location A, machine 3 in location B and the electrical panel board in location B. The flow cost increases to 74 € and the total cost is equal to 281.58 €.

In the following table, we show the total cost by imposing the machines positioning of the flow solution and by changing the position of the electrical panel board.

Position of the electrical panel board	A	B	C
Flow cost [€]	64	64	64
Electric service cost [€]	302,29	278,35	306,12
Total cost [€]	368,29	344,35	372,12
Δ with optimal sol [%]	+30.80	+22.29	+32.15

Table 4: Effect of electrical panel board positioning on the flow solution.

By evaluating the results in table 4, all the solutions that use the machines positioning of the flow solution are not optimal. In the last row, we report the percentage difference between the total cost of the three instances with the different electrical panel board position and the cost of the optimal solution.



	6	10	16	25	35	50	70	95	120	150	185	240
ce1	167,36 €	104,53 €	71,79 €	53,20 €	48,25 €	47,36 €	51,72 €	55,24 €	63,99 €	71,76 €	80,38 €	89,16 €
ce2	63,19 €	41,97 €	32,38 €	28,20 €	30,23 €	34,05 €	42,52 €	48,60 €	58,72 €	67,43 €	76,94 €	86,50 €
ce3	238,98 €	147,54 €	98,88 €	70,38 €	60,64 €	56,51 €	58,05 €	59,81 €	67,61 €	74,74 €	82,75 €	90,99 €

Figure 7: Behavior of ce_i for every machine.

In figure 7, it is shown the calculation of the electrical cable cost per distance unit of the facility *i* ce_i for every machine with the indication of initial section (gray box), that is the first possible section from the point for view of the constraint (11) and the optimal section (black box), where the constraint (11) is satisfied and at the same time the electrical cable cost is minimized. In fact, by changing the section of the electrical cable [mm^2] (x-axis), the cost per distance unit of the electrical cable ce_i changes by following equation (1). As shown in figure 5, the curve for every machine is convex and has a minimum point (black box). In table 5, it is shown the effect on the total electric service cost of the minimization of the electrical cable cost. In particular, it is evaluated the total electric service cost with the optimal position of the machines and the electric panel in the case of use of:

- first possible section of the electrical cables;
- optimal section of the electrical cables.

Thus, adopting the optimal solution instead of the first possible section it is possible to achieve a total cost saving equal to 39.54%.

	Solution	Electrical panel board pos.	Section ep-1 [mm^2]	Section ep-2 [mm^2]	Section ep-3 [mm^2]	Electric service cost [€]	Flow cost [€]	Total cost [€]
First possible section scenario	3-1-2	B	16	10	16	318.93	74	392.93
Optimal section scenario	3-1-2	B	50	25	50	207.58	74	281.58

Table 5: Effect on the total electric service cost of the electrical cable cost minimization.

In table 6 it is illustrated how the solution changes while varying energy costs: if the weight of the electrical service cost if comparable with the flow cost (scenario 1), the solution assumes the value of the flow solution.

Scenario	1	2	3	4	5	6
Energy cost [€/MWh]	10	50	100	200	300	400
Electrical panel board pos.	B	B	B	B	B	B
Solution	3-2-1	3-1-2	3-1-2	3-1-2	3-1-2	3-1-2
Flow cost [€]	64	74	74	74	74	74
Electrical service cost [€]	76.15	109.15	151	207.58	254.85	289.72
Total cost [€]	140.15	183.15	225	281.58	328.85	363.72

Table 6: Effect of electrical panel board positioning on the flow solution.

The previous analyses show that it is necessary to consider explicitly the costs related to sizing of the electrical service in the positioning of machines in a layout.

5. Conclusions

The objective of the paper is to present a variation of the FLP considering the energy costs related to auxiliary systems. In particular, current study considers the effect on the FLP solution of the electrical service cost that depends on the electrical panel board positioning and on the electrical cable sizing. In fact, the installation and operating costs of the electrical service depends on the distance between the electrical panel board and the machines. These two costs depend on the size of the electrical cable. In particular, as shown in the paper, exists a trade-off between the installation cost and the operating cost that permits to optimize the size of the electrical cable.

The solutions show that the electrical service costs can change the optimal solution obtained considering only the flow costs. For the specific example considered the solution that minimizes only material flows (i.e. traditional FLP solution) has a percentage difference with respect the optimal solution cost ranging from +22.29% to +32.15%. Thus, this research shows how it is relevant to consider in the facilities positioning the impact of the electrical service costs.

The possible extension of this research could be the introduction of other auxiliary systems, such as compressed air supply and/or cooling water supply, with the additional complication that in this case there will be also an electrical supply for those additional systems.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

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