Smart Inventory 4.0. Case Study Application to an Italian SME operating in the Cosmetics Sector: Mediterranea Cosmetics belonging to Fratelli Carli Spa, Imperia (ITALY)

Roberto Mosca*, Marco Mosca*, Roberto Revetria*, Fabio Currò*, Federico Briatore*

*Mechanical, Industrial and Transport Engineer Department (D.I.M.E.), University of Genoa, Genoa, GE 16126. Italy (e-mail: roberto.nicola.mosca@gmail.com, marcotulliomosca@gmail.com, roberto.revetria@unige.it, f.curro@tcore.it, federico.briatore@gmail.com)

Abstract: In the current historical moment of transformation of Industries from traditional to 4.0, an important step (both organizational both technological and economic) is represented by the automation of the picking operation in warehouses. The paper illustrates how the use of a plant, developed on purpose by the authors for a medium-sized company in the cosmetics sector, allows for certain global advantages. The proposed system is designed rack-less for reasons of flexibility, with plug and play drawers. It uses what Industry 4.0 makes available in terms of central and distributed intelligence (and related 2-way communication). Direct consequences are the reduction of delivery times, the absence of costly errors for incorrectly shipped products, the decrease in the number of employees and the maximum flexibility in the management of warehouse space. All this against an investment of an amount being widely compatible with the company's cash flow, an investment from which a safe reduction in costs is obtained with a consequent increase in operating margins and the company's competitiveness.

Keywords: Automated storage and retrieval system, Automated warehouse, Automated picking

I. Introduction

A medium-sized Italian Enterprise that trades cosmetics and perfumes wants to evaluate the opportunity to transform the Picking operation, now performed manually by special Operators, into automated picking as already carried out by other companies in the same Sector. The Authors of the paper recommended that the Management, before making a final decision on the matter, to analyze all the aspects of the problem capable of influencing the result of the transformation. Among these aspects, in addition to the 4.0 system model (identified in relation to the spaces occupied with respect to the available spaces), emerges the need to assess both the compatibility of the new installation with the Company warehouse and the margin of space necessary for the upgrading of the system in relation to future increases in production or sales generated by the launch on the Market of new products currently under study and testing. No less important for the success of the transformation is the organizational model to be put in place for the handling of goods arriving at the picking station and leaving the warehouse after packing for shipping. As a last aspect, although of significant importance, a timely economic evaluation of the investment was recommended, as well as the cost / benefit ratio, necessary to implement the transformation of picking from manual to automated.

II. Literature Review

The picking plant object of this case study is described in detail in the paper "A 4.0 Automated Warehouse Storage and Picking System for Order Fulfillment" (produced by the authors Lucia Cassettari, Fabio Currò, Marco Mosca, Roberto Mosca, Roberto Revetria, Stefano Saccaro, Gabriele Galli) and presented at WCE 2021 where it was awarded as the Best Paper Award in the "Manufacturing Engineering and Engineering Management" Section. Please refer to the original paper for the literature review and references, which are omitted in this paper in order to avoid duplication.

III. AS-IS ANALYSIS

A. Infrastructures

The current layout (figure 1) consists of an area of 1,800 square meters, with an asymmetrical usable height of 5 to 6 linear meters and an average volume of 9,500 cubic meters. Shelves are 2.20 meters long and 1 meter wide (capable of housing 2 pallets each) and the distance between the shelves is fixed at 1.30 linear meters (see Fig. 9). The top floor of the shelving makes it possible to accommodate packages with a maximum height of 1

meter (equal to about 3 boxes on a pallet) except for 23 shelves (due to the available asymmetrical height). The shelves are placed, each other, at a distance of 2.20 meters away. 2 roller conveyors, divided into 54 columns per side (108 total), allow easier unloading of the bulky packages. Among the goals of the Management emerges also the possibility to release a portion of the space currently occupied, in order to make it available for other activities.

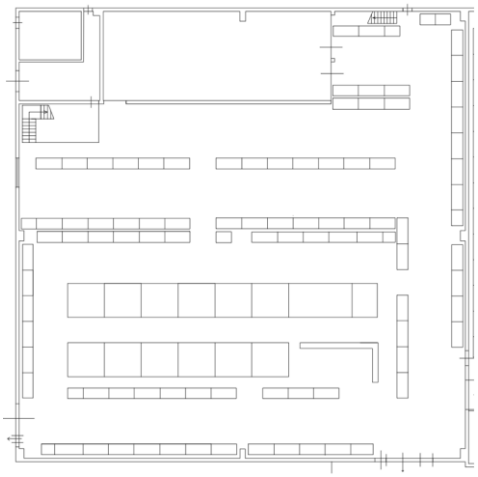


Fig. 1. Current Layout

B. *Applied technologies*

Assuming that nowadays the Company performs exclusively manual picking by means of dedicated Operators, the only technologies in use are related to the phases of:

- Demand forecast;
- Demand planning;
- Communication to the warehouse Operators of the composition of each order mix.

Consequently, the technologies already implemented in the Company at the time of the analysis (figure 2) were found to be inconsistent with the actual needs of managing the products in the warehouse, from purchasing planning to picking them. They consist of:

- MRP (Material Requirement Planning). Indicated in literature as a technique that calculates the net needs of materials and plans production and purchase orders, in consideration of the Market demand, of the bill of materials, of the production, of the purchase lead times and of the actual warehouse stocks. MRP systems are normally very useful for companies that have complex bills of materials and / or relatively long procurement lead times. Considering that the company in question operates a BTS (Buy To Sell) business, which by nature does not involve production (as it is a pure resale of Cosmetics), it would normally not need an MRP software. It is found that the company improperly uses MRP as a demand planning system which is unsuitable, inaccurate and time-consuming;
- STOCKAGER (Warehouse Software). Stockager is a software with warehouse management function. It was implemented to manage individual or distributed warehouses in the area. It adapts to any warehouse layout, following its evolutions over time. The company uses this Software in connection with the corporate ERP to manage orders;
- WAREHOUSE TABLETS. The order queues produced by Stockager are displayed as job orders on the tablets supplied to the Operators.

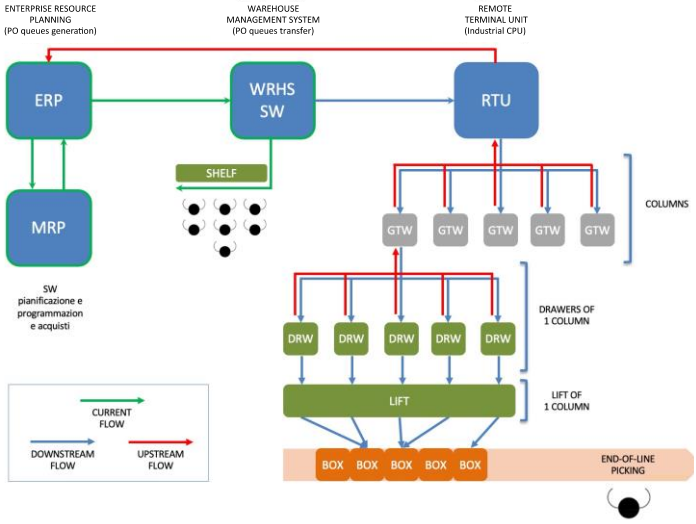


Fig. 2. Old Architecture Vs. New Architecture

C. *Human Resources currently engaged*

Warehouse Operators have the task of receiving products from Couriers, loading products on the shelfs according to warehouse logics and performing picking operations. The number of warehouse Operators varies according to seasonality; however it is calculated on an average basis as 7 FTE / month (Full Time Equivalent). Warehouse Staff generates a significant cost that impacts the margins of the business. In addition, by the very nature of the work (high number of operations and limited time available), the picking operations thus conducted generate continuous Human errors, that worsen performance and damage the corporate image towards Customers.

D. *Existing processes and methodologies*

In accordance with the activities carried out by the Operators, the current warehouse processes are mainly three:

- Demand planning process through MRP;
- Goods receiving process;
- Product shipping process.

A detailed mapping of each of the processes interconnected with the warehouse was carried out and a subsequent analysis to highlight any areas of potential improvement. The following critical issues emerged from this analysis:

- Improper use of the MRP system, which is used as a demand planning tool;
- The "goods loading" on the shelves (associated with low added value activities causing inefficiencies in the handling operations);
- The lack of process automation in picking;
- The use of the tablets significantly slows down the manual activity of picking and packaging;
- The ineffective stocking logic, which leads to excessive movement of goods between warehouses.

IV. Definition of the problem

The analysis of the current situation and of the methods of warehouse management in use in the Company allowed the Authors to develop a clear vision on the causes of the problem. To increase operational efficiency, the market offers multiple solutions for automated picking, valid, but complex, sectoral and expensive, therefore inaccessible both for small volumes (in the order of a few hundred product codes) both for specific Sectors (such as those under analysis: Cosmetics and Beauty). Consequently, many SMEs give up the opportunity to adopt automated warehouse solutions, therefore opting for manual management (by means of picking Operators) even if inefficient and unreliable, thus incurring in a set of common problems.

A. Greater safety for the Operator in Picking Operations

One of the problems, initially neglected, that emerged during the analysis of the traditional plant, turned out to be safety for picking Operators, especially during peak periods, when several Operators insist on the same spaces at the same time, working at a fast pace in order to increase the amount of deliveries. In addition, during the operations of withdrawal at height (where, by "height", is meant over 2m) using precarious means such as ladders. The risk of falling is significant, especially in consideration of the fact that for this type of activity, up to now, the Company had not foreseen the use of dedicated PPE such as harnesses and lanyards. The new system, by eliminating the manual picking operation from the racks, which is delegated to automation, similarly avoids exposing the Operators to this phase of risk.

B. Greater safety for the Operator Picking warehouse loading operations

At the request of the Company, historically particularly sensitive to the safety of the Operators, the Authors are currently studying an automated loading system, designed to extend the level of safety achieved in the picking operations on the front side, to the operations of loading of goods at warehouse on the rear side. The aim is to replace a machine to the Operator during the loading phase, so avoiding the Operator to move the products at height, with the consequent risks.

V. Innovative aspects

Among the innovative aspects of the proposed picking warehouse, the authors highlight, in particular, the fact that the system was designed completely rack-less, with side-by-side columns, each of which consisting of overlapping drawers. This is in order to allow adaptability to any geometry of the warehouse since the system can be extended both horizontally (number of columns) and vertically (number of overlapping drawers). The rack-less solution implies the lack of a fixed metal infrastructure, capable of containing the drawers. It allows both an easy implementation of the system and its possible future growth, including the possibility of complete relocation of the system, where needed. Finally, the system allows for significant savings on the costs of the plant itself, in addition to those related to its production, transport and assembly. The drawers have been conceived in a plug and play logic. It follows that from a mechanical point of view they are designed to create a load-bearing structure by means of the direct interlocking of the same and from an electronic point of view they have each been equipped with dedicated peripheral electronics which, through each column gateway, is able to relate to the center (picking server, communicating in turn with the company server on which the ERP that generates the order queues is installed).

VI. Value added

By acting on the operational reality of a medium-sized company, the advantages that can be achieved by using the proposed system can be highlighted. Management and organizational advantages allow the company to improve its competitiveness on the market, due to the lower labor costs involved in picking, both the higher delivery speed and the elimination of picking errors. This is made possible by a wide adoption of Industry 4.0 technologies. In the literature, no trace has been found any previous used for the same purpose, which gives a further innovative character to the proposed system.

VII. Logistics analysis

A first flow is necessarily made up of goods arriving at the plant. The most rational solution for this flow has been identified as follows:

- Arrange the area in front of the warehouse in a parking area for truck drivers;
- Pick up the incoming goods by means of a forklift;
- Let the loaded forklift follow a path like the one shown in the figure.

As the forklift moves near the various racks, the Operator unloads the products in the same. These products are intended to replenish the competent drawers whenever the system detects proximity to the internal reordering point and signals to the picking Operator the need to replenish the system from the shelving. Currently the warehouse is located in a covered area with a square plan of 3 square meters, where the shelves for the products are positioned as in figure 3. The overall storage capacity of packaged products reaches 800 m3 (by counting two additional racks placed in a neighboring warehouse). Among the objectives indicated by the Management for automation emerges also that of recovering the space occupied by these racks, in order to make it available for other activities. Figure 3 shows the new warehouse layout after the installation of the automated system. The bidirectional arrows placed between the racks highlight the flows of loading and picking, respectively. Once emptied, the forklift will leave the warehouse following the loading path in the opposite direction. It should be noted that the new layout generates a reduction in storage capacity of 16%, from the current 800m3 to approximately 670m3.

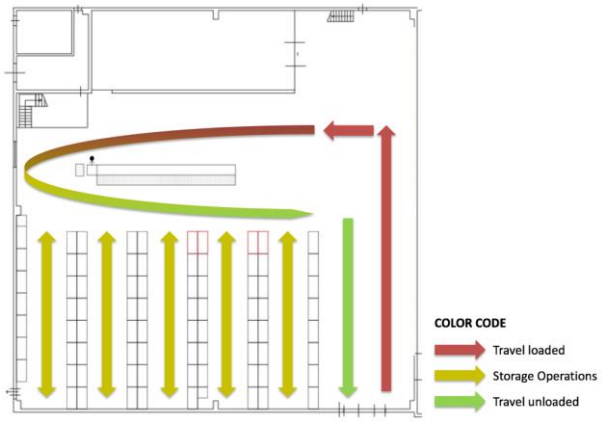


Fig. 3 – Flows regarding the loading of goods in stock and warehouse layout, top view

This reduction is, however, amply compensated by the higher operational speed of automated picking, a characteristic which, if properly used, allows both a reduction in stored stocks and consequently in the necessary storage space, both avoiding the need to increase the shelving for future upgrading of the business, according to the predictions of the Sales Office reported in the previous. Figure 4 shows the shelving designed by the Authors to cope with the above; made up of the assembly of 300 drawers, it develops horizontally for a length of 13.75m, vertically for a height of 3m and a depth of 1.05m. At this point, the Authors wanted to evaluate the availability of space necessary for any further upgrading of the plant in the event of a hypothetical favorable situation that will lead to doubling the volumes of products currently sold in the next 10 years. In this hypothesis, the number of drawers needed would go from the current 300 to 616 with an increase of 316 drawers, drawers which, if suitably arranged horizontally and vertically, bring the dimensions of the system respectively to (Ref. Fig. 4):

- Depth: 1.05m (unchanged);
- Length: 15,40m Vs. initial 13,75m;
- Height: 5.50m Vs. initial 3m.

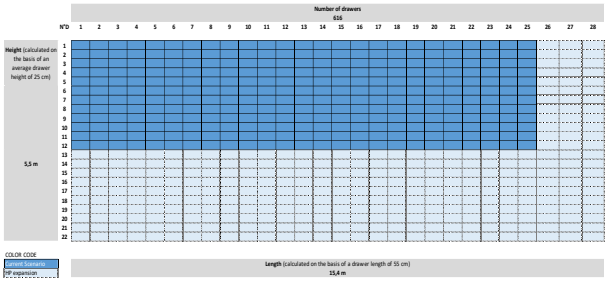


Fig. 4 - Automated picking warehouse, front view

It is important to note that not only are the new dimensions compatible with those of the warehouse, but they are such as to allow additional spaces to be left free; for this reason, it could be possible to increase it further (by expanding to the space currently used for maneuvering vehicles and / or other activities). The picking line is refilled by using a forklift which collects the goods stocked in the shelves located on the back (figure 5). The flow out from the warehouse is carried out by loading the packaged goods on the forklift and transferring them to the Couriers waiting in the courtyard, used for deliveries to Customers. The path of the forklift has been designed to create a closed cycle, for maximizing the use of the vehicle, with the related management and economic advantages (figure 6).

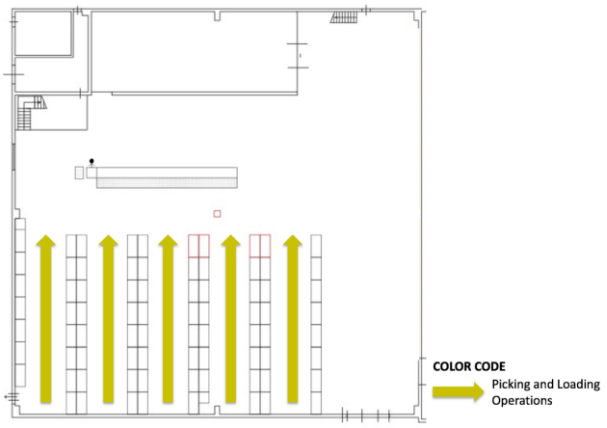


Fig. 5 - Flows regarding the loading of goods to the picking machine and warehouse layout, top view

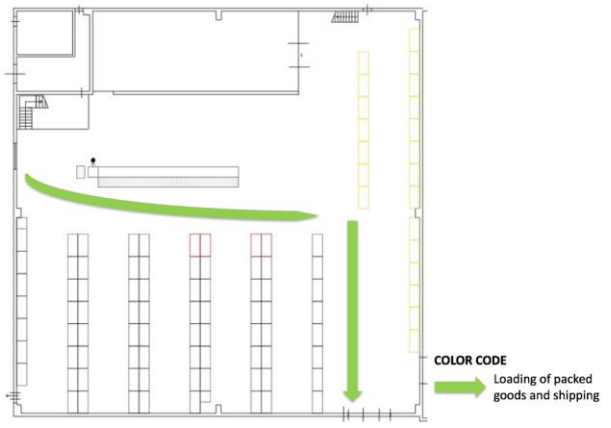


Fig. 6 - Flows regarding the unloading of goods for shipping and warehouse layout, top view

Again in the case of the aforementioned future increase in the business, it is also of certain importance to point out that the costs of the Operators assigned to the automated plant do not increase in proportion to the higher volumes handled as, thanks to the high flexibility of the plant, only one extra Operator allows to cope with an almost double capacity of the current picking.

VIII. Robustness Analysis

It is certainly important to point out that the layout has been designed in a robust way, to avoid the risk that any possible cause of unavailability of the system (e.g. maintenance, breakdown, blackout, ..) would provoke the interruption of Customer deliveries, with the consequent damage. In fact the plant design, in such cases, allows to carry out picking manually.

IX. Economic Analysis

Having specified that, according to the contractual indications with the Manufacturer, it has been assumed a Life Cycle of the plant equivalent to 20 years, two different hypotheses of utilization were made:

A. Prudential: the volumes handled by Company picking remain constant over time, therefore no increases in sales are expected in future years;

B. Optimistic: according to the forecasts of the Sales Office, which deems a gradual increase in sales to be achievable up to a doubling of current volumes over the next 10 years.

Stated that, in order to conduct the analysis, it is necessary to establish the relevant costs and revenues to be accounted for each of the 20 years of the investment time horizon.

A. Costs

Within the first year, the total estimated costs will amount to € 307,330 (including: feasibility studies, design and logistics, purchase of the plant, preparation of warehouse spaces). From the third to the twentieth year, the maintenance costs, borne by the manufacturer in the first two years of activity, are borne by the Company with an annual contractual outlay of € 10,000. The cost of energy necessary for the operation of the plant was considered negligible as well as the costs of decommissioning, in the hypothesis of revamping of the plant at the end of the standard life cycle.

B. Equivalent revenues

TABLE I
PERSONNEL COST

	CURRENT SCENARIO		FUTURE SCENARIO	
	PERSONNEL	MONTHLY COST	PERSONNEL	MONTHLY COST
JANUARY	6	€ 17.500,00	1	€ 2.916,67
FEBRUARY	6	€ 17.500,00	1	€ 2.916,67
MARCH	6	€ 17.500,00	1	€ 2.916,67
APRIL	4	€ 11.666,67	1	€ 2.916,67
MAY	4	€ 11.666,67	1	€ 2.916,67
JUNE	4	€ 11.666,67	1	€ 2.916,67
JULY	4	€ 11.666,67	1	€ 2.916,67
AUGUST	4	€ 11.666,67	1	€ 2.916,67
SEPTEMBER	4	€ 11.666,67	1	€ 2.916,67
OCTOBER	4	€ 11.666,67	1	€ 2.916,67
NOVEMBER	6	€ 17.500,00	1	€ 2.916,67
DECEMBER	6	€ 17.500,00	1	€ 2.916,67
TOTAL		€ 169.166,67		€ 35.000,00
COST AVOIDED				€ 134.166,67

TABLE II
TAX BENEFIT SIMULATION

TAX BENEFITS			
Depreciation		**17,5%**	*% applied to € 225,930.00 corresponding to the cost of the drawers*
Monthly payment	€	44.787,75	*annual for 5 years*
Tax (IRAP / IRES) recovery for amortization			
IRES		24%	
IRAP		4,250%	
Tax recovery	€	12.652,54	*annual for 5 years, from 2021*
Tax credit			
% recovered		40%	
Portion refunded	€	102.372,00	*part of € 255.930,00 corresponding to the cost of the drawers*
Annual repayment	€	20.474,40	*annual for 5 years, from 2022*
TOTAL BENEFIT			
2021	€	12.652,54	*pure recovery*
2022	€	33.126,94	*recovery plus refund*
2023	€	33.126,94	*recovery plus refund*
2024	€	33.126,94	*recovery plus refund*
2025	€	33.126,94	*recovery plus refund*
2026	€	20.474,40	*pure refund*
TOTAL	€	165.634,70	

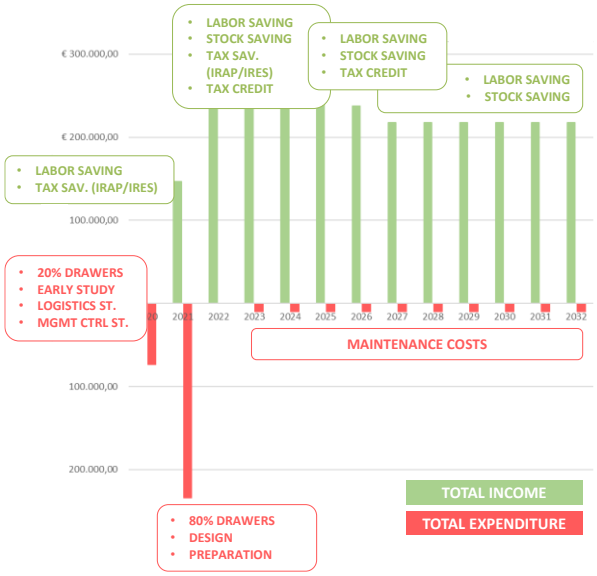
They are represented by the reduction in labor costs, due to the lower number of Operators involved in picking, resulting from the installation of the automated system. To these must be added the tax benefits currently granted by the Italian State to Companies that modernize their production Structures in a 4.0 logic.

Given that the installation of the new plant will make it possible to reduce the number of picking Employees to a single Operator and that the full monthly cost for the Company is equal to € 2,916 / Operator, it can be deduced (Ref. Tab. 1) that the savings obtainable for each year will be equal to € 134,166. The tax benefits currently granted by the Italian State (in the form of tax credit, hyper amortization, tax recovery consequent to the investment) lead to a total cost recovery of € 165,634, to be divided over a period of 5 years (Ref . Tab. II). The reduction in the quantities of products in stock is due to the better operation of the new plant (according to sales forecasts), and allows for lower annual costs from the decrease of fixed assets, equal to € 83,280 for the years 2-6-7.

C. Equivalent evaluation

Starting from the cost / revenue data set out above, it is now possible to proceed with an assessment of the economic validity of the new plant. The analysis was conducted using the classic indicators of the Theory of Investments, namely the Payback Period (PBP), the Net Present Value (NPV), the Discounted Profitability Ratio (RRA) and the Internal Rate of Return (IRR), where:

- PBP represents the time frame over which the accumulated profits allow to repay the investment;
- NPV represents the value created by the project;
- RRA represents the percentage of return of the discounted investment over its life cycle;
- IRR is the value of the discount rate "i" which leads to a zeroing of the NPV. It is calculated in order to evaluate the safety margin between the current value of "i" and possible increases of the same (meaning the cost of money).



- Fig. 7. Cash Flow simulation

The PBP can be easily calculated using the income-expenditure graph (shown above), from which it can be deduced a time frame lower than 2 years and its reach by 2022. This figure is also certainly positive in view of a favorable investment assessment, as it frees up cash in a very short time. The NPV, calculated using the formula is equal to 1.887.801€. This figure also appears, in absolute value, in favor of the investment, if compared with the initial investment cost of € 307,324.

$$\sum_{t=1}^{n} \frac{F_t}{(1+i)^t} - F_0$$

The RRA, calculated using the formula

$$\frac{\sum_{t=1}^{n} F_t \times (1+i)^{-1}}{F_0}$$

customized to the case in question, it becomes 1.887.801,89€ / 307.324€ = 6,1427€

therefore RRA = 614%. Value, again, decisively in favor of the validity of the investment, as the capital invested at time zero generates, over the 20 years of useful life, an economic return of 614%.he IRR can be calculated both graphically, by linearly joining two NPV values (one positive and one negative) sufficiently close to each other to make the linear approximation of the NPV trend acceptable. Otherwise it can be used the definition of IRR itself, according to which the IRR is the value to zeroing NPV, by solving the equation

$$\sum_{t=1}^{n} \frac{F_t}{(1+IRR)^t} - F_0 = 0$$

From the graph below it can be obtained a value of "i" included in the range 0,2-0,25.

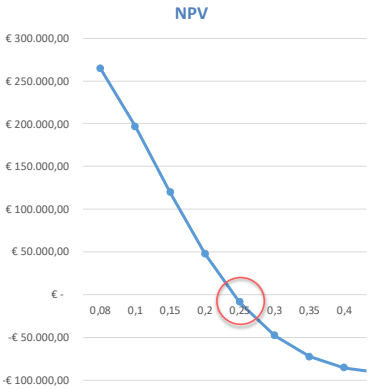


Fig. 8. Net Present Value simulation

Even assuming i = 0.20 prudently, it can be observed that compared to the value assumed as a reference i =

0.08 it is so much higher as to highlight a strong protection of the investment from possible future increases in the cost of money.

D. Results of the economic analysis

The investment required for the purchase of the automated picking plant identified by the Management gives largely positive results both from an operational and an economic point of view. The results shown for the economic evaluation are related to the current data of the Italian reality, but the calculation model, appropriately generalized and parametric by nature itself, can be easily applied by replacing the specific data (such as Operator cost, tax benefits, cost of first installation, etc.) to any other national reality.

X. CONCLUSIVE REFLECTIONS

The case study carried out highlights how the automated picking plant chosen by the Management can meet all the expectations of the Company both in the current situation and after appropriate expansion, in the event of a doubling of sales volumes in the next 10 years (as well as strategically planned by the Sales and Marketing Department). The high flexibility of the plant makes it possible to face this growth without incurring additional investments (such as new spaces), but simply with the increase of a single Operator. It should also be noted that the investment will bring the Company, in addition to the target operational advantages, substantial economic benefits both in the short and long term. In particular, the latter, which are of fundamental importance for a medium-sized company that cannot risk being overwhelmed by an incorrect valuation of the investments made, even if of a modest amount in absolute value, have proved to be particularly favorable, generating a positive return on the investment over its life cycle and a return of the invested capital in a very short time. Finally, the robustness of the selected solution (from all Operational and Economic profiles) is not negligible, a robustness that gives full confidence of being able to positively face the many situations that inevitably arise during Operations. These considerations lead to the conclusion that the Management's decision to focus on an automated picking warehouse leads to expected results, fully in line with the Company's expectations.

XI. SPECIAL THANKS

The Authors of the paper extend a warm thanks to the Owners and Staff of the Fratelli Carli Spa Company in Imperia, where the comparison analysis between manual and automated picking was conducted, for the kind welcome reserved for them and for their availability to provide the information and quantitative data, that allowed a detailed analysis of the two picking situations. The Company has provided us with such valuable help, which is essential to be able to carry out an analysis with a concrete confirmation in the Operational reality and without which there would be the risk of making even gross errors of assessment. The Authors also thank the Technological Partner mcGEAR for the fundamental support provided in the conceptualization and design of the system.

REFERENCES

[1] K. J. Roodbergen, I.F.A. Vis, "A survey of literature on automated storage and retrieval systems", *European Journal of Operational Research, pp.* 343-362, 2009.

[2] L. Ghomri, Z. Sari, "Mathematical modeling of the average retrieval time for flow-rack automated storage and retrieval systems", *Journal of Manufacturing Systems, pp.* 165-178.

[3] M. Sri Sarat Chandra, S. Bhanu Murthy, "Design and development of an automated storage organizer", *Materials Today: Proceedings, 2018.*

[4] T. Liu, Y. Gong, R.B.M. De Koster, "Travel time models for split-platform automated storage and retrieval systems", *International Journal of Production Economics, pp.* 197-214, 2019

[5] G. Dukic, T. Opetuk, T. Lerher, "A throughput model for a dual-tray vertical lift module with a human order-picker", *International Journal of Production Economics, 170*, pp. 874-881, 2015

[6] M. Kazemi, A. Asef-Vaziri, T. Shojaei, "Concurrent optimization of shared location assignment and storage/retrieval scheduling in multi-shuttle automated storage and retrieval systems", *IFAC-PapersOnLine, pp.* 2531-2536, 2019

[7] S. Brezovnik, J. Gotlih, J. Balič, K. Gotlih, M. Brezočnik, "Optimization of an automated storage and retrieval systems by swarm intelligence" *Procedia Engineering, pp.* 1309-1318, 2014

[8] S.S. Chakravorty, "Improving distribution operations: Implementation of material handling systems", *International Journal of Production Economics, 122*(1), 89-106. 2008

[9] N. Boysen, S. Fedtke, F. Weidinger, "Optimizing automated sorting in warehouses: The minimum order spread sequencing problem", *European Journal of Operational Research* 270, pp. 386-400, 2018

[10] L. Nicolas, F. Yannick, H. Ramzi, "Order batching in an automated warehouse with several vertical lift modules: Optimization and experiments with real data", *European Journal of Operational Research, pp.* 958-976, 2018

[11] M. Calzavara, F. Sgarbossa, A. Persona, "Vertical lift modules for small items order picking: An economic evaluation", *International Journal of Production Economics* 210, pp. 199-210, 2019

[12] V. Lototsky, R. Sabitov, G. Smirnova, B. Sirazetdinov, N. Elizarova, S. Sabitov, "Model of the automated warehouse management and forecasting system in the conditions of transition to industry 4.0", *IFAC-PapersOnLine, pp.* 78-82, 2018

[13] D. Mourtzis, V. Samothrakis, V., Zogopoulos, E. & Vlachou, "Warehouse design and operation using augmented reality technology: A papermaking industry case study", *Procedia CIRP, pp.* 574-579, 2019

[14] M. Calzavara, R. Hanson, F. Sgarbossa, L. Medbo, and M. I. Johansson, "Picking from pallet and picking from boxes: A time and ergonomic study", *IFAC-PapersOnLine* 50, pp. 6888-6893, 2017

[15] O.K. Efthymiou, S.T. Ponis, Current Status of Industry 4.0 in Material Handling Automation and In-house Logistics, *International Journal of Industrial and Manufacturing Engineering*, pp. 1370-1374, 2019

[16] M. Demartini, F. Tonelli, L. Damiani, R. Revetria, and L. Cassettari, "Digitalization of manufacturing execution systems: The core technology for realizing future smart factories", *Proceedings of the Summer School Francesco Turco*, 2017.

[17] S. Gotthardt, M. Hulla, M. Eder, H. Karre, H., C. Ramsauer, "Digitalized milk-run system for a learning factory assembly line", *Procedia Manufacturing*, pp. 175-179, 2019

[18] Cassettari, L., Currò, F., Mosca, M., Mosca, R., Revetria, R., Saccaro, S., Galli, G., "A 4.0 automated warehouse storage and picking system for order fulfillment", WCE 2021, ICMEEM_210312Rf, accepted and included in the conference proceedings published by IAENG (ISBN: 978-988-14049-2-3)