

separately for the 2 different Scenarios A and B. The following tables show the costs attributable to the individual years of the life of the new plant (Table 5 and Table 6), compared to the “Current Spending” illustrated in Table 4, deriving from the use of external companies. The basic data for the construction of these tables are described in the previous paragraphs.

3.1 Current Spending

Table 4. Spending (with External Companies)

Sanitization by Ext. Companies	Treatments/month =>		30
Scenario B (30 sani/month)	Cost / treatment	Area	Spending
YEAR 1	[€/smq]	[sqm]	[€]
Spending (month)	1 €	2064	61.920 €
Spending (year)			743.040 €

Table 5. 10 sanitizations/month (Scenario A)

SCENARIO A			
Sanitization by new 4.0 machines	Treatments/month =>		10
YEAR 1-12	Months	Cost/month	Cost/life cycle
Months 1-12 => 12 months	[#]	[€/month]	[€/life cycle]
Spending (excluding maintenance)	12	240 €	2.880 €

Table 6. 30 sanitizations/month (Scenario B)

SCENARIO B			
Sanitization by new 4.0 machines	Treatments/month =>		30
YEAR 1-12	Months	Cost/month	Cost/life cycle
Months 1-12 => 12 months	[#]	[€/month]	[€/life cycle]
Spending (including maintenance)	12	810 €	9.720 €

Please note that for both the Scenarios analyzed, the cost of decommissioning at the end of the life cycle must be considered.

3.2 Indicators

The analysis was conducted using the classic indicators of the Theory of Investments, specifically the Payback Period (PBP) and the Net Present Value (NPV).

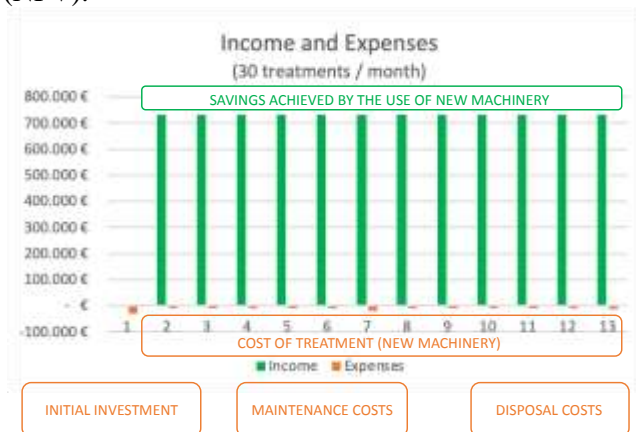


Fig. 2: Cash flow (new equipment)

The PBP can be easily calculated using the income-expenditure graph illustrated in Figure 2 (investment / yearly CF), with an exceptional time

frame, lower than one month, so simplifying the assessment of the investment, by releasing the cash in a short time.

The NPV is calculated using the formula:

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

In this case, the NPV represents the total savings expected using the new technology, updated at time zero. As such, in Table 7 we present the PBP and NPV for 10 treatments/month (SC. A). Similarly, in Table 8 we showcase the PBP and NPV for 30 treatments/month (SC. B).

Table 7. PBP and NPV for 10 treatments/month (SC. A)

SCENARIO A			
10 treatments /months	YEAR 0	YEAR ...	YEAR 12
	2021	...	2033
Discounting exponent	0,0	...	5,0
Expenses			
Investment	32.000 €		
Maintenance cost			excluded
Disposal cost			5.000 €
Income (annual benefit)			
Expenditure saving		...	733.320 €
Total income	- €	...	739.800 €
Total Expenses	- 32.000 €	...	- 8.240 €
Cash flow (CF)	- 32.000 €	...	731.560 €
Cumulative cash flow	- 32.000 €	...	8.801.720 €
i = discount rate	8,0%	...	
Discounted cash flow	- 32.000 €	...	461.007 €
PbP (Pay Back Period)	0,04	Y	
NPV (Net Present Value)	6.908.487	€	

Table 8. PBP and NPV for 30 treatments/month (SC. B)

SCENARIO B			
30 treatments /months	YEAR 0	YEAR ...	YEAR 12
	2021	...	2033
Discounting exponent	0,0	...	5,0
Expenses			
Investment	32.000 €		
Maintenance cost			9.600 €
Disposal cost			5.000 €
Income (annual benefit)			
Expenditure saving		...	733.320 €
Total income	- €	...	733.320 €
Total Expenses	- 32.000 €	...	- 14.720 €
Cash flow (CF)	- 32.000 €	...	718.600 €
Cumulative cash flow	- 32.000 €	...	8.636.600 €
i = discount rate	8,0%	...	
Discounted cash flow	- 32.000 €	...	452.840 €
PbP (Pay Back Period)	0,04	Y	
NPV (Net Present Value)	6.778.690	€	

4 Conclusion

However, in the need to raise the current performance at least from 2 sanitizations to 10/month, with a target value of 30/month, the Management has required the Authors to study (in addition to the technical feasibility) the economic sustainability of the new 4.0 technology, to understand the impact on the Structure's economy. The result of the study conducted is largely favorable for the Structure as the analysis of the investment, carried out both for Scenario A and for Scenario B, demonstrates two significantly positive values for NPV (6.8ME of discounted savings) and PBP (less than 2 years), along the useful life cycle of the new machinery (assumed prudently in 12 years). According to the Management's mandate, the impact of the investment on the structure's cash flow was then assessed, demonstrating full sustainability with a widely positive cash flow along the whole life cycle. The results induced the Management to adopt the 4.0 technology identified. This decision was a source of sincere satisfaction for the Authors as they are convinced that they have made a positive contribution to the fight against viruses and bacteria that, in a globalized world, will progressively generate more dangerous threats. The test case also highlights the possibility for companies that deal with sanitization to use the proposed methodology to replace chemical products, with a clear impact on economics (significant cost reduction), and benefits for People's safety and the environment. The results of the analysis also highlight the fact that companies that deal with sanitization can use the proposed methodology, to replace the current chemical products, with clear economic benefits for them and environmental benefits for Humanity. Also, in this case, Engineering 4.0 has shown the capability to provide adequate support to healthcare activities. In consideration of this, the Authors decided to direct a significant part of their research to support Medical, Surgical, and Nursing Equips.

References:

- [1] Mosca, R., Mosca, M., Revetria, R., Cassettari, L., Currò, F., Galli, G. (2021). "Sanitizing of Confined Spaces Using Gaseous Ozone Produced by 4.0 Machines", WCE2021 Best Paper Award, ICSBB_210312Rx. Conference proceedings published by IAENG, ISBN: 978-988-14049-2-3.
- [2] Apuzzo, Dario, and Membro di ISCO. "Uso potenziale dell'ozono nella SARS-CoV-2/COVID-19." Comitato Scientifico Internazionale d'Ozonoterapia ISCO3. ISCO3 / EPI / 00/04 (Madrid, 14 marzo 2020). Approvato da ISCO3 il 13/03/2020.
- [3] Menzel DB. Oxidation of biologically active reducing substances by ozone. Arch Environ Health. 1971 Aug;23(2):149-53. DOI: 10.1080/00039896.1971.10665973. PMID: 4397679.
- [4] van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, Tamin A, Harcourt JL, Thornburg NJ, Gerber SI, Lloyd-Smith JO, de Wit E, Munster VJ., Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1, The New England Journal of Medicine, 2020; 382:1564-1567, DOI: 10.1056/NEJMc2004973.
- [5] Fortini, G., and C. C. Cardoso. Guidelines for the use of gaseous ozone in the sanitization of meat product processing environments ("Linee guida per l'utilizzo dell'ozono gassoso nella sanificazione degli ambienti di lavorazione di prodotti a base di carne"). 2016. SSICA Research Foundation.
- [6] A. Scroccarello, F. Della Pelle, M. Del Carlo, D. Compagnone (2022). Monitoring disinfection in the Covid-19 era. A reagent-free nanostructured smartphone-based device for the detection of oxidative disinfectants. Microchemical Journal 175 (2022) 107165. <https://doi.org/10.1016/j.microc.2021.107165.0026-265X>, 2021 Elsevier B.V.
- [7] M.C. Celina, E. Martinez, M.A. Omana, A. Sanchez, D. Wiemann, M. Tezak, T.R. Dargaville (2020), Extended use of face masks during the COVID-19 pandemic - Thermal conditioning and spray-on surface disinfection, Polymer Degradation and Stability 179 (2020) 109251. <https://doi.org/10.1016/j.polyimdegradstab.2020.109251>. 0141-3910/–© 2020 Published by Elsevier Ltd.
- [8] S. AlZain (2018), Effect of 0.5% glutaraldehyde disinfection on surface wettability of elastomeric impression materials. Saudi Dental Journal (2019) 31, 122-128. <https://doi.org/10.1016/j.sdentj.2018.10.002>. 1013-9052–©2018 The Author. Production and hosting by Elsevier B.V. on behalf of King Saud University.

- [9] N. D. Hollis, J.M. Thierry, A.G. Garcia-Williams (2020). Self-reported handwashing and surface disinfection behaviors by U.S. adults with disabilities to prevent COVID-19, Spring 2020. *Disability and Health Journal* 14 (2021) 101096. <https://doi.org/10.1016/j.dhjo.2021.101096>. 1936-6574/Published by Elsevier Inc.
- [10] W. A. Rutala and D. J. Weber (2001). Surface disinfection: should we do it? *Journal of Hospital Infection*. 48 (Supplement A): S64-S68. DOI: IO. I053/jhin.200 I .0973. 0 200 I The Hospital Infection Society. 0195-670 I/O I/OAOS64.
- [11] G. McDonnell a, P. Burke (2011). Disinfection: is it time to reconsider Spaulding? *Journal of Hospital Infection* 78 (2011) 163e170. 0195-6701/\$ e see front matter, 2011 The Healthcare Infection Society. Published by Elsevier Ltd. All rights reserved. DOI: 10.1016/j.jhin.2011.05.002
- [12] S. Petti, G.A. Messano (2016). Nano-TiO₂-based photocatalytic disinfection of environmental surfaces contaminated by meticillin-resistant *Staphylococcus aureus*. *Journal of Hospital Infection* 93 (2016) 78-82. <http://dx.doi.org/10.1016/j.jhin.2016.01.020>. 0195-6701/a 2016 The Healthcare Infection Society. Published by Elsevier Ltd.
- [13] K. Steinhauer, T.L. Meister, D. Todt, A. Krawczyk, L. Paüvogel, B. Becker, D. Paulmann, B. Bischoff, M. Eggers, S. Pfaender, F.H.H. Brill, E. Steinmann (2021). Virucidal efficacy of different formulations for hand and surface disinfection targeting SARS CoV-2. *Journal of Hospital Infection* 112 (2021) 27-30. <https://doi.org/10.1016/j.jhin.2021.03.015>. [0195-6701/](https://doi.org/10.1016/j.jhin.2021.03.015), 2021 The Healthcare Infection Society.
- [14] W. A. Rutala and D. J. Weber (2016). Monitoring and improving the effectiveness of surface cleaning and disinfection. <http://dx.doi.org/10.1016/j.ajic.2015.10.039>.
- [15] K. Gallandat, R. C. Kolus, T. R. Julian, D. S. Lantagne (2020). A systematic review of chlorine-based surface disinfection efficacy to inform recommendations for low-resource outbreak settings. *American Journal of Infection Control* 49 (2021) 90, à103. <https://doi.org/10.1016/j.ajic.2020.05.014>. [0196-6553/](https://doi.org/10.1016/j.ajic.2020.05.014), 2020 The Author(s). Published by Elsevier Inc. on behalf of Association for Professionals in Infection Control and Epidemiology, Inc.
- [16] S. Thakar, R. K. Malhan, P. M. Bhatt, S. K. Gupta (2021). Area-Coverage Planning for Spray-based Surface Disinfection with a Mobile Manipulator. *Robotics and Autonomous Systems* 147 (2022) 103920. <https://doi.org/10.1016/j.robot.2021.103920>. [0921-8890/](https://doi.org/10.1016/j.robot.2021.103920), 2021 Elsevier B.V.
- [17] S. J. Volkoff, T. J. Carlson, K. Leik, J. J. Smith, D. Graves, P. Dennis, T. Aris, D. Cuthbertson, A. Holmes, K. Craig, B. Marvin & E. Nesbit (2020). Demonstrated SARS-CoV-2 Surface Disinfection Using Ozone. *Ozone: Science & Engineering. The Journal of the International Ozone Association*. 43:4, 296-305, DOI: 10.1080/01919512.2020.1863770.
- [18] A. M. Wilson, K. A. Reynolds, J. D. Sexton, R. A. Canalesa (2018). Modeling Surface Disinfection Needs To Meet Microbial Risk Reduction Targets. *American Society for Microbiology. Public and environmental health microbiology. Applied and environmental microbiology*. September 2018 Volume 84 Issue 18 e00709-18. DOI: <https://doi.org/10.1128/AEM.00709-18>.
- [19] G. Molina Roja (2020), Use of ozone for sanitizing environments in the dental practice. Evaluation of effectiveness and health consequences ("Utilizzo dell'ozono per la sanificazione degli ambienti nello studio odontoiatrico. Valutazione dell'efficacia e conseguenze per la salute"). ANDI Associazione Nazionale Dentisti Italiani. 16 Giugno 2020.
- [20] Mosca, R., Mosca, M., Revetria, R., Currò, F., Briatore, F., (2022). "Fighting Hospital Infections with Engineering 4.0", Conference Paper, Lecture Notes in Networks and Systems "Advances in System-Integrated Intelligence", 2022, 546 LNNS, pp. 310-317, Springer, Lecture Notes in Networks and Systems, 2023, 546 LNNS, pp. 235-244, ISSN 2367-3370, ISBN: 978-3-031-16280-0, DOI: 10.1007/978-3-031-16281-7.
- [21] Mosca, R., Mosca, M., Revetria, R., Currò, F., Briatore, F., (2022). Engineering Solutions 4.0 in the fight against the spread of Covid 19 A new Methodology including processes, procedures and devices. AIDI - Italian Association of Industrial Operations Professors. Proceedings of the Summer School Francesco Turco 2022 27th Summer School Francesco Turco, 2022. Code 286459. ISSN: 22838996.

- [22] G. Katara, N. Hemvani, S. Chitnis, V. Chitnis, D.S. Chitnis (2008). Surface disinfection by exposure to germicidal UV light. *Indian Journal of Medical Microbiology*, (2008) 26(3): pp.241-42. DOI: 10.4103/0255-0857.42034
- [23] V. Fejes, D. Szucs, K. Sipos, V. S. Poor (2022). Effect of ozone disinfection on forensic STR profiling. *Forensic Science International* 333 (2022) 111212. <https://doi.org/10.1016/j.forsciint.2022.111212>. 0379-0738/, 2022 The Author(s). Published by Elsevier B.V.
- [24] E. Tchouaket Nguemeleu, S. Robins, S. Boivin, D. Sia, K. Kilpatrick, B. Dubreuil, C. Larouche, N. Parisien and J. Letourneau (2021). A pre-pandemic COVID-19 assessment of the costs of prevention and control interventions for healthcare associated infections in medical and surgical wards in Quebec. *BMC (Part of Springer Nature). Antimicrobial Resistance & Infection Control*. (2021) 10:150. <https://doi.org/10.1186/s13756-021-01000-y>.

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