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Assessment and Improvement of Anti-COVID-19 Measures in Higher Education Establishments

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Abstract: This paper presents a comprehensive methodology for evaluating and improving the anti-Coronavirus (COVID-19) measures in higher education establishments. The methodology combines the use of: (1) Building Information Modeling (BIM) for the integration and control in a 3D graphic environment the anti-COVID-19 safety measures; (2) a questionnaire to collect the students' commitment to safety measures and their suggestions to improve these measures; (3) data analysis to explore the impact of the students' profiles on their commitment to safety measures. The proposed methodology is applied at the engineering school Polytech'Lille in the North of France. Results show that the BIM model provides valuable services to the administration by integrating the safety measures in a 3D environment and checking the compatibility of these measures and their improvement. The use of the questionnaire allows the administration to collect students' feedback about their commitment to safety measures and their suggestions to improve these measures.

Keywords: COVID-19; BIM; higher education; safety; questionnaire; students; access; disinfection; cameras

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1. Introduction

Beginning in 2020, a new virus known as COVID-19 has been considered as a severe hazard to human lives [1]. The virus might be transmitted from one human to another through respiratory droplets [2]. Those droplets reach uninfected people from two sources: infected people and contaminated surfaces [3,4]. Given its high infection and mortality rates, COVID-19 is classified as a global epidemic [5]. As of April 2021, around 136 million people have been infected, and 2.54 million people passed away [6]. In addition, COVID-19 largely disturbed social and economic activities, which constitute the main pillars of sustainable development.

Due to the slow vaccination rate and the absence of efficient medication for COVID-19, countries and organizations imposed protective measures to limit the spread of the virus. The World Health Organization (WHO) recommended commitments to personal protection measures (e.g., use of hand sanitizing, surfaces disinfection, and face masks) and physical distancing measures [7]. On the other hand, governments organized awareness campaigns concerning the risk of COVID-19, its symptoms, transmission modes, and prevention methods, and they encouraged online learning [8].

In some countries, such as France, the Ministry of Education allowed higher education establishments to open with a maximum of 50% occupancy in classrooms with the necessary safety measures [9]. The universities face unique challenges in providing in-person instruction during the COVID-19 pandemic [10]. They have to figure out a set of modifications and improvements to regular operations to protect students and staff [11]. Researchers in Taiwan suggested that higher education establishments could reopen safely with a combination of approaches that comprise containment (access control) and mitigation (sanitation, ventilation, and physical distancing) practices [12].

According to Megahed and Ghoneim [13], COVID-19 hazard control should involve the following layers of defense inside buildings:

- Hazard elimination: understand the COVID-19 symptoms and mode of transmission.
- Engineering and construction control: re-design or adjust building configuration, functions, and systems to incorporate healthier building strategies.
- Administrative and technical controls: instructing individuals on what to do based on the updates and new measures.
- Personal protective equipment: related to the people's protection from the virus because people are the key source of the virus transmission.
- Measures Implementation: provide the necessary safety measures inside a building.

The virus spread has pushed the world to change and introduce new concepts and rules to their daily habits, especially in common spaces, such as sanitizers and social distancing requirements. Several national and international groups of expertise proposed guidelines to implement anti-COVID-19 measures. For example, the MASS group, which specialized in designing a living environment, established a guideline for redesigning restaurant spaces [14]. In addition, Working Groups (WGs) suggested a document helping school managers to redesign schools through sustainable actions [15]. Higher education establishments are concerned by the evaluation and improvement of anti-COVID-19 measures. Recently, Vozzoli [16] proposed tools to improve the anti-COVID-19 measures in schools, universities, and workplaces.

Considering the vital role of buildings management in addressing pandemic challenges, both researchers and professionals proposed using digital technology to improve the implementation of anti-COVID-19 safety measures in buildings. Ramadass et al. [17] suggested using video surveillance to identify individuals' behavior that does not comply with physical distancing requirements. Sathyamoorthy et al. [18] highlighted the importance of Thermal Imaging Cameras (TC) in fighting against COVID-19. Other scholars and professionals focused on the use of BIM in implementing anti-COVID-19 safety measures for its high capacity in: (1) effective lifecycle management of buildings [19–21]; (2) indoor risk management [22–24]; and (3) spatial health risk evaluation [25]. Chen et al. and Luo et al. [26,27] reported that China used BIM to construct two emergency hospitals in the first period of COVID-19. BIM proved to be effective in the rapid design and construction and the organization of emergency operations. Li et al. [28] developed a BIM model to evaluate the indoor infection risk using data concerning the built environment, occupancy, and pathogen transmission. Pavon et al. [29] used BIM for real-time identification of individual paths and facilities occupancy ratio to limit individuals' crossing. Considering the vital role of ventilation in reducing the COVID-19 Spread [30,31], some scholars proposed to use BIM to monitor the indoor air quality [32–34]. In a recent paper, Delval et al. [35] presented the use of BIM to assess COVID-19 risk management concerning indoor air ventilation. They used the BIM model to analyze risk related to the space configuration and ventilation system in schools. Leon et al. [36] developed a BIM-based approach to improve the implementation of anti-COVID-19 safety measures, including (1) optimization of classroom occupancy, (2) respecting the safety distances, (3) improving disinfection and waste management, and (4) assessment of a natural ventilation system.

Previous works on implementing the anti-COVID-19 safety measures focused on digital technology, including smart monitoring and BIM. The users' feedback and experience were not considered to assess and improve the efficiency of the implemented solutions. Since users' experience is vital in improving services, including digital services, this paper proposes to combine the use of BIM and users' feedback to assess and enhance the anti-COVID-19 system. The research was based on data collected in the school of engineering Polytech'Lille in the North of France. A questionnaire was used to collect the students' evaluation of the anti-COVID-19 safety measures, as well as their opinion and suggestions about the extension of these measures. A COVID-19 layer was created in the BIM model of the school of engineering to integrate the COVID-19 safety measures in the building management system. This layer aimed to create a shared digital space to integrate and illustrate safety measures, optimize classroom capacity and indoor circulation paths, data and information update, and improve students' awareness.

2. Materials and Methods

2.1. Methodology

Figure 1 shows the methodology used in this research to evaluate and improve measures taken by higher education establishments to prevent COVID-19 spread. It includes 3 phases: (1) use of BIM for the spatial modeling of the anti-COVID-19 measures through the creation of COVID-19 Layer in the BIM model that integrates and shares 3D environment data and information about the anti-COVID-19 safety measures; (2) use of a questionnaire to collect students' evaluations of the COVID-19 measures efficiency as well as their suggestions to enhance these measures; (3) data analysis and recommendations.

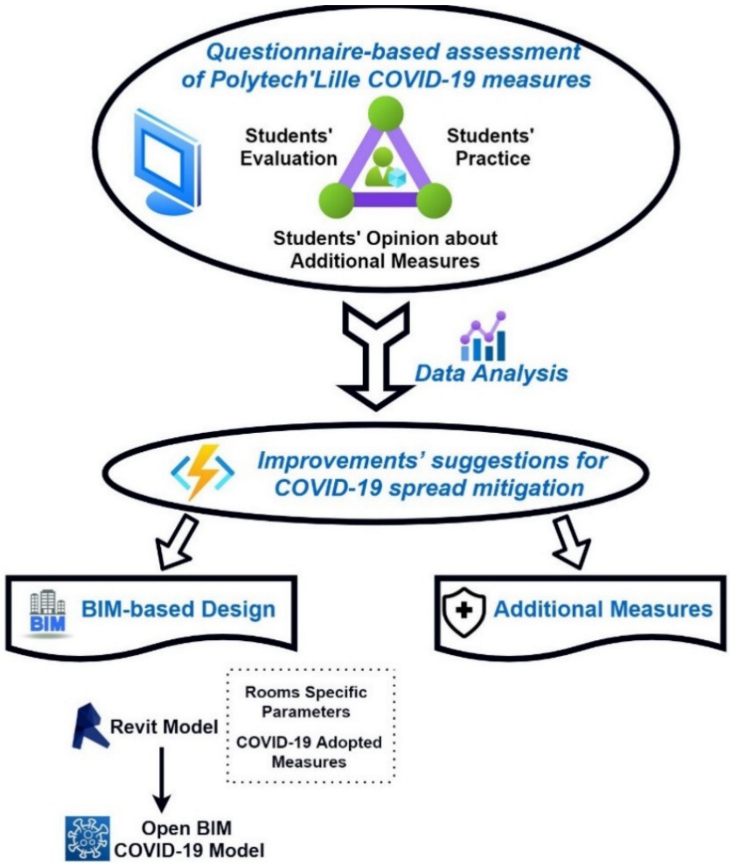

Figure 1. General Methodology.

The use of BIM allows the building managers to integrate the buildings' components and information into a friendly environment [37]. In addition, BIM could represent and check the compatibility of safety measures with guidelines comprehensively. This methodology could be easily extended to other educational establishments. The BIM model could integrate real-time data from sensors to enhance safety measures. The questionnaire could be conducted regularly to improve both the safety measures and the students' awareness.

The anti-COVID-19 layer in the BIM model includes access restrictions in the building, localization of hand gel and Disinfection Products (DP), classroom capacity and desks' localization, circulation indications, and any additional measures. The BIM model could also include Surveillance Cameras (SVC) to control the anti-COVID-19 measures [38]. Access to these cameras is limited to the administration in charge of the building's safety and security [39]. The BIM model could be accessed via the administration, faculty members, and students via the online application. The administration is responsible for data and information updates. Users could use the model to notify any deficiency in the anti-COVID-19 system.

The questionnaire was used to evaluate safety measures taken by the administration and involve students in the improvement of the efficiency of these measures. This approach has been used to analyze the COVID-19 situation from different perspectives. University students have been considered as a target population in many studies, especially in research related to the mental health and psychological impact of COVID-19 [40–43]. Other studies have evaluated students' knowledge, perceptions, and practices involving COVID-19 measures [44–47]. However, questionnaires were used to assess the effect of COVID-19 on students' life without development goals.

The questionnaire included closed-ended questions, which are better for gathering quantitative data [48]. The questionnaire aimed to collect the students' evaluation of and respect towards the anti-COVID-19 measures and their recommendations to improve them. The students' feedback is helpful for the administration to understand the acceptability of the restriction and precaution measures, as well as their efficiency.

Data analysis was conducted with an emphasis on (1) analysis of the students' perception of the anti-COVID-19 measures and their suggestions to improve these measures; and (2) the correlation between the students' profile and their feedback about the anti-COVID-19 measures. Analysis was conducted with SPSS Statistics 20 software, which is largely used to analyze quantitative data, especially in social and health science research [49,50]. The descriptive analysis was presented as frequencies, percentages, and medians, whereas categorical measures were described as means with standard deviation. Two independent samples t-tests or one-way analysis of variance (ANOVA-test) could be used to explore the impact of the students' profile on their perceptions of the anti-COVID-19 measures. These tests are the keystone of data analysis in several fields such as economics, biology, sociology, and psychology [51]. They are used to determine if there are any statistically significant differences among the means of two or more groups [52]. When comparing only two groups, both tests could be used since they use the identical *p*-values, knowing that F values are equal to the square of t values [53]. However, the ANOVA-test has some advantages. Several reports have indicated that the ANOVA-test is among the most popular inferential data analysis techniques employed in educational research [54–56].

In this research, data analysis was carried out using the ANOVA-test with a 95% confidence level. Consequently, a difference of p-value < 0.05 is considered statistically significant. Assumptions of the ANOVA-test regarding the data normal distribution, the homogeneity of variance, and sample independence were properly checked before using the test.

2.2. Application to the Engineering School Polytech'Lille

2.2.1. Presentation of Polytech'Lille

The proposed methodology was applied to the public engineering school Polytech'Lille, situated near the city of Lille in the North of France. Polytech'Lille provides engineering education to about 2000 students. The total area of the school buildings is around 20,000 m^2. Figure 2 shows the architecture of the school, including three 4-floor buildings and a common ground floor. The ground floor comprises a hall, amphitheaters, WCs, cafeteria, and offices. Other floors have mainly classrooms and offices.

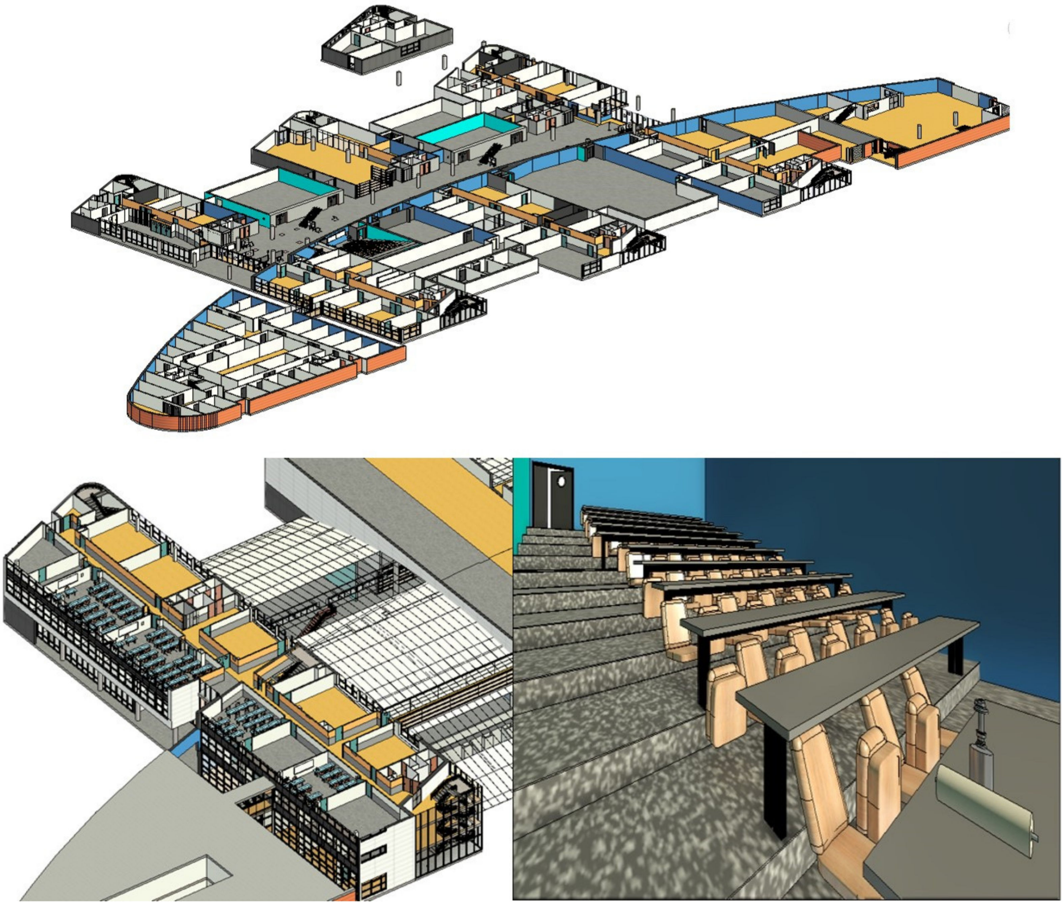

Figure 2. Polytech'Lille BIM Model.

A BIM model was established for Polytech'Lille to implement the COVID-19 measures. This model provides a 3D representation of the building, including rooms, facility areas, architectural components (doors, windows, walls), furniture, and occupancy numbers.

2.2.2. Anti-COVID-19 Measures at Polytech'Lille

In May 2020, Polytech'Lille implemented the government safety regulations associated with the COVID-19 epidemic. These measures concerned awareness instructions, Building Access (BA) restriction, indoor circulation paths, Closure of Common Spaces (CCS), surfaces disinfection, hand sanitizer services at the entrance, in the hall, and classrooms. The safety measures were added as a COVID-19 layer in the BIM Model. Figure 3 shows the safety measures at the school entrance and in the classrooms as integrated into the BIM model.

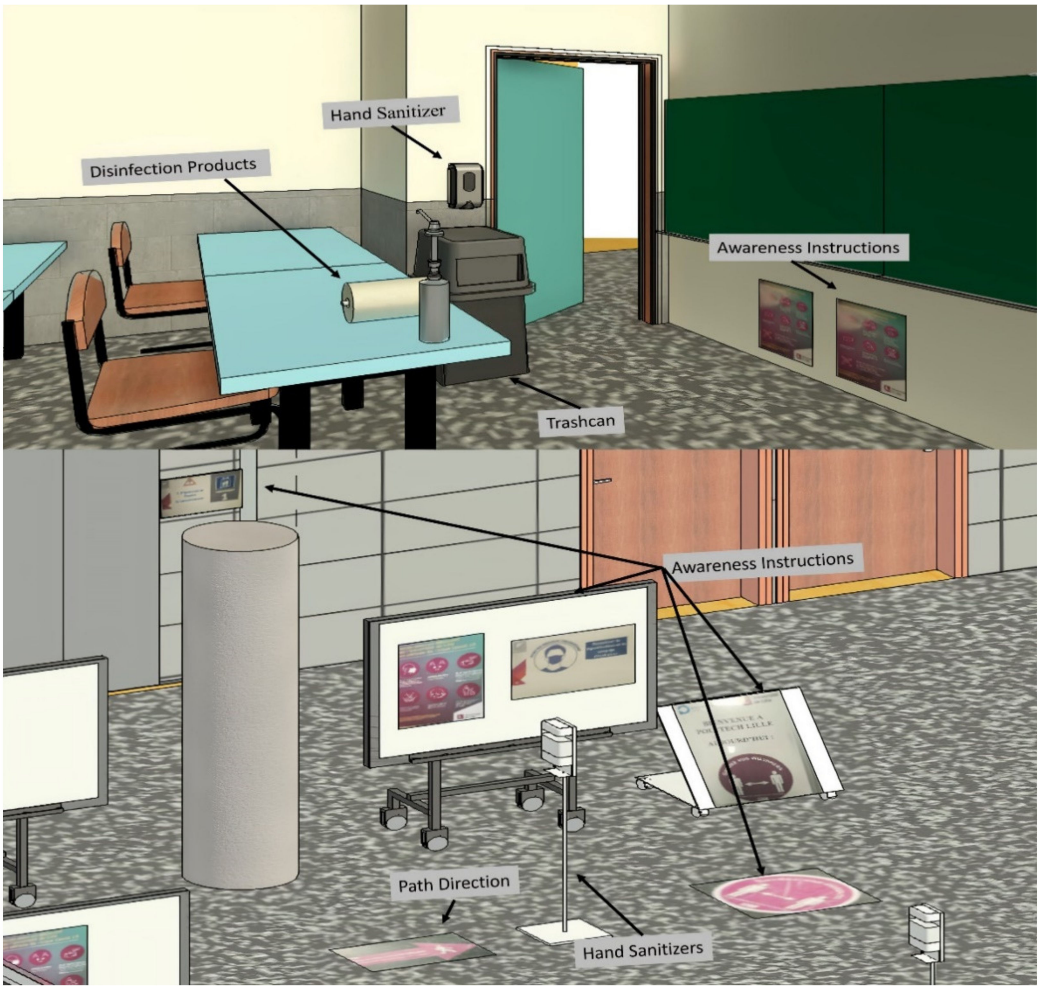

Figure 3. Illustration of the anti-COVID-19 measures in the BIM model.

2.2.3. Use of a Questionnaire for the Assessment of Anti-COVID-19 Measures

A web-based questionnaire was used to assess the COVID-19 safety measures in the school and the students' commitment to these measures. The questions were based on Likert-scale 5 points questions. The questionnaire consisted of four parts (Table 1).

Table 1. Composition of the questionnaire.

Questionnaire Parts	Questions
Part 1: general information	Gender Education degree (bachelor's or master's degree) Use of the mobile application "TousAntiCovid"
Part 2: assessing COVID-19 safety measures taken by Polytech'Lille	To what extent do the following measures are efficiently performed in Polytech'Lille? Hand sanitizer at the entrance Hand sanitizer in the hall Hand sanitizer in classrooms Disinfection Products Access restrictions Path direction organization Closure of common areas

Table 1. *Cont.*

Questionnaire Parts	Questions
Part 3: assessing students' commitment to the COVID-19 safety measures	To what extent are you committed to the following measures? Hand sanitizer at the entrance Hand sanitizer in the hall Hand sanitizer in classrooms Path direction Surfaces Disinfection upon arrival Surfaces Disinfection at the end of the course Social distancing
Part 4: Students' suggestions about additional measures	What is your opinion concerning the implementation of the following additional measures? Thermal camera (without facial recognition) Surveillance cameras (without facial recognition) to verify compliance with measures A social network of information about COVID-19Common spaces available to students while respecting social distancing

The first part included general information about the students' profiles. It consisted of questions about gender, level of education, and the national anti-COVID-19 mobile application "TousAntiCovid". This application includes general information about COVID-19 and services to track users' contact with alerts to users who had contact with positive COVID-19 people. By November 3, 2020, around 7.2 million users had downloaded this application in France. The use of this application by students constitutes an indicator of their awareness and commitment to anti-COVID-19 measures.

The second part of the questionnaire concerned the students' evaluation of the school anti-COVID-19 measures. These measures cover the BA restriction, Path Direction (PD) organization, CCS, Disinfection Products (DP), and hand sanitizers.

The third part aimed to explore the students' commitment to anti-COVID-19 measures. Students were asked about their commitment to the following measures: hand sanitizer, disinfection of tables upon arrival, and after the course, PD, and Social Distancing (SD) inside the building.

The fourth part of the questionnaire concerned the students' opinions about additional measures such as: (1) implementation of SVC to check the students' respect towards safety measures (e.g., physical distancing and mask-wearing); (2) use of TC at the building entrance to measure students' body temperature; (3) the creation of a Social Network (SN) to share COVID-19 information; and (4) access to Common Spaces (CS).

The questionnaire was targeted to the bachelor's and master's students in Polytech'Lille (Population (Pop) equal to 190). Accordingly, the sample size for infinite population (SSIP) and the required sample size (SS) were calculated based on the Cochran formula [57].

$$SSIP = \frac{Z^2 p(1-p)}{e^2} \tag{1}$$

$$SS = \frac{SSIP}{1 + \left(\frac{SSIP-1}{Pop}\right)} \tag{2}$$

The Z value corresponding to the 95% confidence interval, the margin of error (e), and the population proportion (p) were taken to be equal to 1.96, 0.1, and 0.5, respectively. Accordingly, the required SS was found to be 65.

3. Results and Discussion

3.1. Students' Profile

A total of 65 students participated in this survey. Table 2 summarizes the students' profiles. It shows that the survey included more males (65%) than females (35%), and more bachelor's students (60%) than master's students (40%). In addition, 29% of the participants indicated using the TousAntiCovid application. ANOVA-test results indicated no significant difference between genders regarding using the TousAntiCovid application (F = 0.024, $p > 0.1$). Both genders showed nearly the same level of commitment in using the TousAntiCovid application (30%). On the other hand, the education level impacted the use of the TousAntiCovid application (F = 3.674, $p = 0.05$). The application adoption ratio amongst the master's degree students (42%) was twice that of the bachelor's degree students (21%).

Table 2. Students' Profiles.

Characteristic	Total(n = 65), n%	With TousAntiCovid Application (n = 19, 29%)	Without TousAntiCovid Application (n = 46, 71%)	F	p-Value
Gender				0.024	0.877
Female	23 (35)	7 (30)	16 (70)		
Male	42 (65)	12 (29)	30 (71)		
Education Degree				3.674	0.05
Bachelor's	39 (60)	8 (21)	31 (79)		
Master's	26 (40)	11 (42)	15 (58)		

3.2. Students' Evaluation of the Anti-COVID-19 Measures

Figure 4 shows the evaluation by the students of the anti-COVID-19 measures, which concern both disinfection and access restrictions. The disinfection measures included the availability of DP, Gel at the Entrance (GE), Gel at the Hall (GH), and Gel in Classrooms (GC). The access measures contained restrictions of the BA, PD, and CCS.

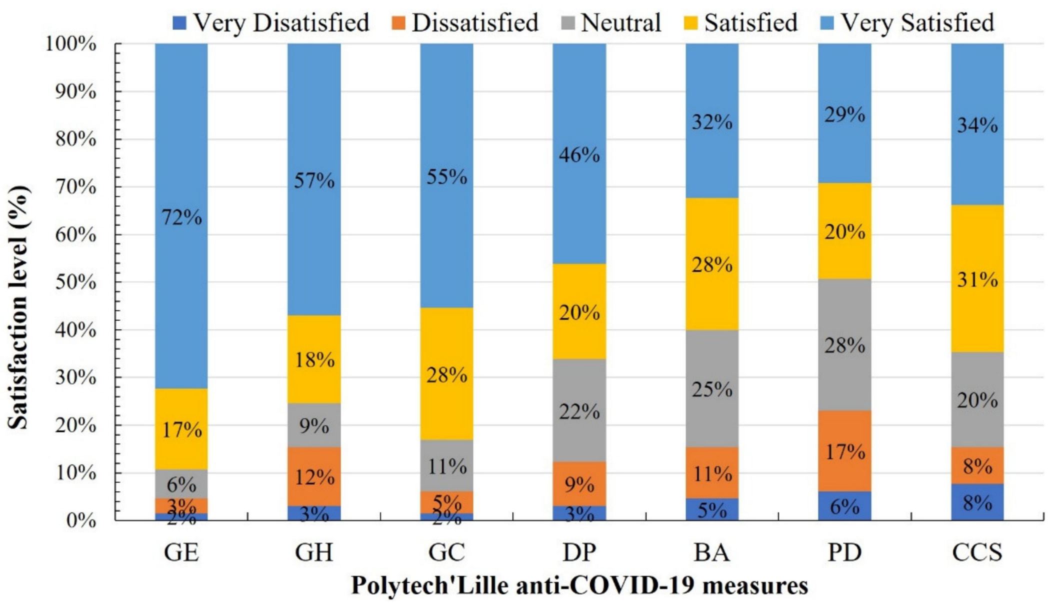

Figure 4. Students' opinions about anti-COVID-19 measures.

Disinfection measures reported a higher satisfaction score (satisfied to very satisfied) than access measures. The satisfaction score for disinfection measures ranged between 66% and 89%, while the score for access measures ranged between 49% and 65%.

The overall average score for disinfection measures was 4.23 ± 1.04. The DP had the lowest "very satisfied" record (46%), while GE had the highest "very satisfied" score (72%).

More than 75% of the students gave a satisfaction score concerning the gel measures (GE, GH, GC). Amongst the 75%, more than 50% were "very satisfied". This result indicates the necessity to provide hand sanitizers in all spaces.

The overall average score for access measures was 3.5 ± 1.21. The highest satisfaction score was recorded in the CCS (65%). A total of 60% of the students provided a satisfaction score for the BA restriction. The lowest satisfaction score (49%) was recorded for the PD. This low score suggests rethinking of this measure is needed by the school.

Influence of the students' profile: Table 3 summarizes the relationship between the students' profiles (gender, education degree, and use of the TousAntiCovid mobile application) and evaluations of the anti-COVID-19 measures. Statistically significant differences were found based on genders regarding students' assessments of the disinfection measures ($F = 4.68$, $p = 0.03$), while no significant difference was observed concerning the access measures ($F = 1.58$, $p > 0.05$). A high satisfaction score was reported by both genders for disinfection measures (74–95% in females, 61–88% in males), compared to access measures (53–69% in females, 45–60% in males).

Table 3. Students' evaluation of anti-COVID-19 measures.

Category	Measures	Satisfaction Level (%)										F	p-Value
		1	2	3	4	5	1	2	3	4	5		
		Gender											
		Female					Male						
Disinfection Measures	GE	0	4	4	13	78	2	2	7	19	69	4.68	0.03 *
	GH	4	9	4	13	70	2	14	12	21	50		
	GC	0	0	4	30	65	2	7	14	26	50		
	DP	4	9	13	17	57	2	10	26	21	40		
Access Measures	BA	9	9	22	22	39	2	12	26	31	29	1.58	0.21
	PD	4	9	30	13	43	7	21	26	24	21		
	CCS	9	9	13	17	52	7	7	26	33	26		
		Education Degree											
		Bachelor's					Master's						
Disinfection Measures	GE	3	5	8	15	69	0	0	4	19	77	1.19	0.27
	GH	5	13	15	18	49	0	12	0	19	69		
	GC	3	5	13	33	46	0	4	8	19	69		
	DP	5	10	18	21	46	0	8	27	19	46		
Access Measures	BA	5	10	21	26	38	4	12	31	31	23	0.36	0.55
	PD	5	18	28	15	33	8	15	27	27	23		
	CCS	8	10	13	28	41	8	4	31	35	23		
		Use of the TousAntiCovid Mobile Application											
		No					Yes						
Disinfection Measures	GE	2	4	7	20	67	0	0	5	11	84	5.11	0.02 *
	GH	4	11	11	22	52	0	16	5	11	68		
	GC	2	2	13	33	50	0	11	5	16	68		
	DP	4	9	24	17	46	0	11	16	26	47		
Access Measures	BA	4	11	26	33	26	5	11	21	16	47	0.03	0.85
	PD	4	15	28	24	28	11	21	26	11	32		
	CCS	7	11	13	35	35	11	0	37	21	32		

* $p < 0.05$; 1: Very Dissatisfied, 2: Dissatisfied, 3: Neutral, 4: Satisfied, 5: Very Satisfied.

Generally, females gave higher satisfaction scores compared to males. On the other hand, females and males disagreed on the access measures ranking. Females considered the CCS as the most satisfying measure and the PD as the less satisfying one. At the same time, males declared the BA as the highest satisfied measure and PD as the lowest. Furthermore, males were "very satisfied" equally between access measures (23%).

Results did not reveal a statistically significant difference between the evaluation of bachelor's and master's degree students concerning their evaluation of anti-COVID-19 measures. However, the satisfaction score for disinfection measures was higher than access measures. In disinfection measures, master's degree students have a higher satisfaction score than bachelor's degree students, except for DP.

On the other hand, concerning the students' evaluation for disinfection measures, a statistically significant difference was found based on the use of the TousAntiCovid mobile application ($F = 5.11$, $p = 0.02$). Nevertheless, no statistically significant differences were observed based on the use of the TousAntiCovid mobile application for access measures ($F = 0.03$, $p > 0.05$). Students who use the TousAntiCovid mobile application gave a higher satisfaction score than other students for disinfection measures. In both PD and CCS, students who do not use the TousAntiCovid mobile application gave higher satisfaction scores.

3.3. Students' Commitment to Anti-COVID-19 Measures

Students were asked about their degree of practicing hand sanitizers, surfaces disinfection, and distancing measures. The hand sanitizers included GE, GH, and GC. Surfaces Disinfection consisted of cleaning when Arriving (SDA) and before Leaving (SDL) the room. Distancing measures comprised SD and PD.

Figure 5 presents a synthesis of the students' responses. It shows that the highest students' commitment concerned hand sanitizers (4.29 ± 1.02) followed by distancing measures (3.54 ± 1.16), then surface disinfection (3.14 ± 1.43). The strong commitment (high to very high practice) ranged from 68% to 92%, 28% to 58%, and 42% to 53% for hand sanitizers, surfaces disinfection, and distancing measures, respectively. Distancing measures presented the highest number of students with "moderate practice". On the other hand, surface disinfection had the highest number of students with "no practice".

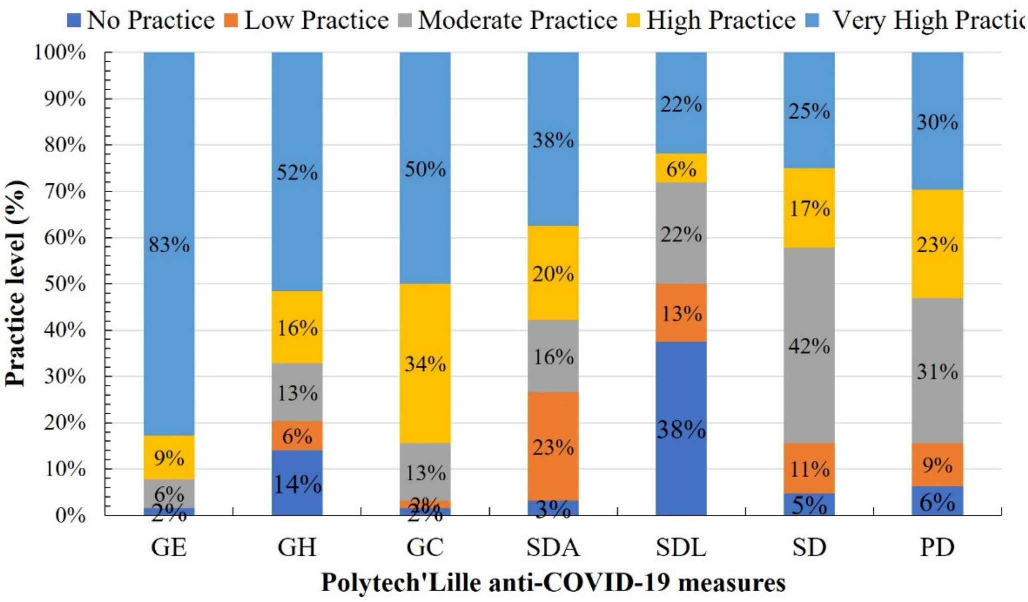

Figure 5. Students' practices involving Polytech'Lille safety measures.

The highest use of hand sanitizers was at the school entrance. In total, 92% of students claimed a strong commitment to using hand sanitizers at the gate. No students presented a "weak practice" of GE; only 2% did not use GE at all. GC has a higher strong commitment (84%) than GH (68%). This result could be related to the higher possibility of touching surfaces in the classrooms than in the hall.

The students' responses revealed a remarkable difference in practice degree between SDA and SDL. SDA (58%) recorded a strong commitment of double SDL (28%). Amongst all measures, the highest number of students with no practice was reported at the SDL (38%). Such results indicate that students care more about protecting themselves than protecting others.

In both SD and PD, students with "no practice" to "weak practice" represented approximately 15%. SD reported the highest "moderate practice" (42%), followed by PD (31%). Students with a strong commitment are higher for PD (53%) than SD (42%). Therefore, the school should improve PD and students' respect for SD.

Influence of students' profiles: Table 4 shows the impact of students' profile on their commitment to respect the anti-COVID-19 measures. For both genders, GE showed the highest strong commitment, followed by GC and GH. Nonetheless, females had a "very high practice" for hand sanitizers (52–83%) compared to males (43–83%). Females were more committed to using hand gels (4.38 ± 0.95) than males (4.15 ± 1.25). In surface disinfection, a slight difference was recorded between genders with a strong commitment (males: 28–59%, females: 26–57%). Males had a higher commitment to following the instructions related to SD and PD (45%, 55%) than females (39%, 48%). However, on average, females (3.52 ± 1.34) were more committed to respecting distancing measures than males (3.43 ± 1.23).

Table 4. Influence of students' profile on their commitment to respecting anti-COVID-19 measures.

Category	Measures	Practice Level (%)										F	p-Value
		1	2	3	4	5	1	2	3	4	5		
		Gender											
		Female					Male						
Hand Sanitizers	GE	0	0	9	9	83	2	0	5	10	83	0.31	0.58
	GH	9	9	22	9	52	17	5	7	21	50		
	GC	0	4	9	26	61	2	0	14	40	43		
Surfaces Disinfection	SDA	9	30	4	22	35	0	19	21	21	38	0.88	0.35
	SDL	43	9	22	4	22	33	14	24	7	21		
Distancing Measures	PD	13	4	35	13	35	2	12	31	29	26	0.13	0.72
	SD	0	9	52	4	35	7	12	36	26	19		
		Education Degree											
		Bachelor					Master						
Hand Sanitizers	GE	3	0	8	10	79	0	0	4	8	88	9.12	0.003 **
	GH	21	10	8	18	44	4	0	19	15	62		
	GC	3	3	15	41	38	0	0	8	27	65		
Surfaces Disinfection	SDA	3	26	18	18	36	4	19	12	27	38	3.39	0.07
	SDL	46	18	13	5	18	23	4	38	8	27		
Distancing Measures	PD	5	5	31	26	33	8	15	35	19	23	0.22	0.64
	SD	5	10	44	23	18	4	12	38	12	35		

Table 4. *Cont.*

Category	Measures	Practice Level (%)										F	p-Value
		1	2	3	4	5	1	2	3	4	5		
		Use of the TousAntiCovid Mobile Application											
		No					Yes						
Hand Sanitizers	GE	2	0	4	11	83	0	0	11	5	84	4.96	0.02 *
	GH	17	9	11	22	41	5	0	16	5	74		
	GC	2	2	13	39	43	0	0	11	26	63		
Surfaces Disinfection	SDA	4	26	15	24	30	0	16	16	16	53	1.46	0.23
	SDL	35	13	28	7	17	42	11	11	5	32		
Distancing Measures	PD	7	9	35	24	26	5	11	26	21	37	3.83	0.05 *
	SD	7	13	41	24	15	0	5	42	5	47		

* $p < 0.05$, ** $p < 0.01$; 1: No Practice, 2: Low Practice, 3: Moderate Practice, 4: High Practice, 5: Very High Practice.

A statistically significant difference was found based on the education degree concerning students' use of hand sanitizers (F = 9.12, p = 0.003). No statistically significant difference was detected regarding students' practices involving surfaces disinfection and distancing measures based on the academic degree. Master's degree students were more committed to respecting the anti-COVID-19 measures (3.92 $\pm$ 1.08) than bachelor's degree students (3.52 $\pm$ 1.35). The strong commitment concerned GE (bachelor: 92%, master: 96%), while the lowest one concerned SDL (bachelor: 26%, master: 28%).

Concerning the students' commitment to using hand sanitizers and distancing measures, a statistically significant difference was observed based on the use of the TousAntiCovid mobile application (F = 4.96, p = 0.02; F = 3.83, p = 0.05). The mean value for students' commitment to using the mobile application (4.02 $\pm$ 1.11) was higher than for other students (3.54 $\pm$ 1.31). This result indicates that students who use the TousAntiCovid mobile application have a higher commitment to respecting the anti-COVID-19 measures than other students.

3.4. Students' Opinion About Additional Anti-COVID-19 Measures

Students were asked about their opinion concerning additional safety measures such as implementing TC at the school entrance and SVC, creating a SN, and reopening the CS.

Figure 6 provides a synthesis of the students' opinions about the suggested additional safety measures. It could be observed that students were more favorable to the CS reopening (4.37 $\pm$ 0.96) and less favorable to the SVC implementation (3.29 $\pm$ 1.57). More than 50% of students suggested that they "strongly agree" with additional measures (CS: 87%, TC: 73%, SN: 68%) except for SVC (50%). Neutral responses were higher for SVC application (20%), and for "disagree" and "strongly disagree" responses (30%). This opinion was related to privacy concerns. The high approval of the CS reopening illustrated the difficulty of group work in the current situation. Only 6% of respondents suggested that they "disagree" to "strongly disagree" with CS reopening.

A high mean value for TC acceptance was observed (4.05 $\pm$ 1.15). Students supported the importance of controlling body temperature at the building entrance. Furthermore, only 17% of students suggested that they "disagree" to "strongly disagree" with the SN creation. The mean value was 3.88 $\pm$ 1.22. This result reflects students' enthusiasm towards SN creation. Such a network will help to share COVID-19 updates and to allocate the surrounding positive COVID-19 cases.

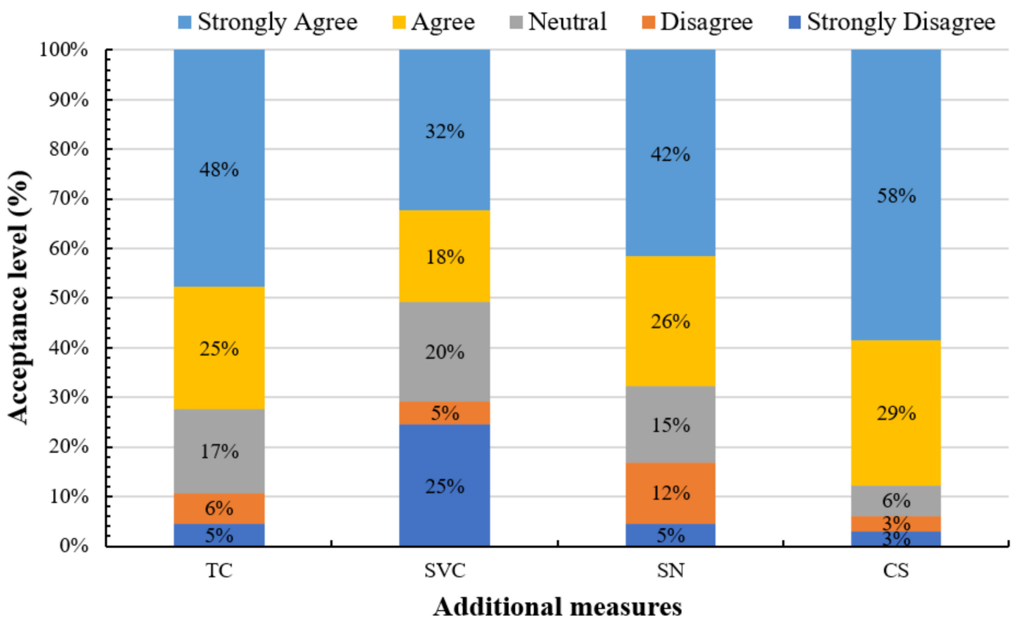

Figure 6. Students' opinions about additional safety measures.

Influence of students' profiles: Table 5 and Figure 7 show that the students' opinions about additional anti-COVID-19 measures depended on their profile. A statistically significant difference was observed based on gender concerning student's opinions for the suggested measures (F = 4.27, $p = 0.04$). The highest difference between males and females concerned SVC (males: 3, females: 5). A total of 33% of males and 22% of females did not approve the idea of installing SVC. More than 64% of males and 70% of females suggested that they "agree" to "strongly agree" with the TC, SN, and CS implementation. The lowest variance was recorded for both genders for CS (females: 0.61, males: 1.11). This result indicates that both genders have almost the same favorable judgment about CS reopening.

Table 5. Influence of students' profiles on acceptance of additional anti-COVID-19 measures.

Measures	**Acceptance Level (%)**										**F**	***p*-Value**
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**		
	Gender											
	Female					Male						
TC	4	9	17	13	57	5	5	16	31	43	4.27	0.04 *
SVC	22	0	9	17	52	26	7	26	19	22		
SN	0	4	22	22	52	7	17	12	28	36		
CS	0	4	4	40	52	5	2	7	24	62		
	Education Degree											
	Bachelor's					Master's						
TC	5	7	21	21	46	4	4	11	31	50	1.32	0.25
SVC	23	5	26	15	31	27	4	11	23	35		
SN	8	13	13	25	41	0	11	19	27	43		
CS	5	5	5	26	59	0	0	7	35	58		

Table 5. *Cont.*

Measures	Acceptance Level (%)										F	p-Value
	1	2	3	4	5	1	2	3	4	5		
	Use of the TousAntiCovid Mobile Application											
	No					Yes						
TC	6	9	13	26	46	0	0	26	21	53	0.38	0.54
SVC	20	6	24	20	30	37	0	10	16	37		
SN	6	15	11	31	37	0	5	26	16	53		
CS	4	2	4	29	61	0	5	11	31	53		

* $p < 0.05$; 1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree.

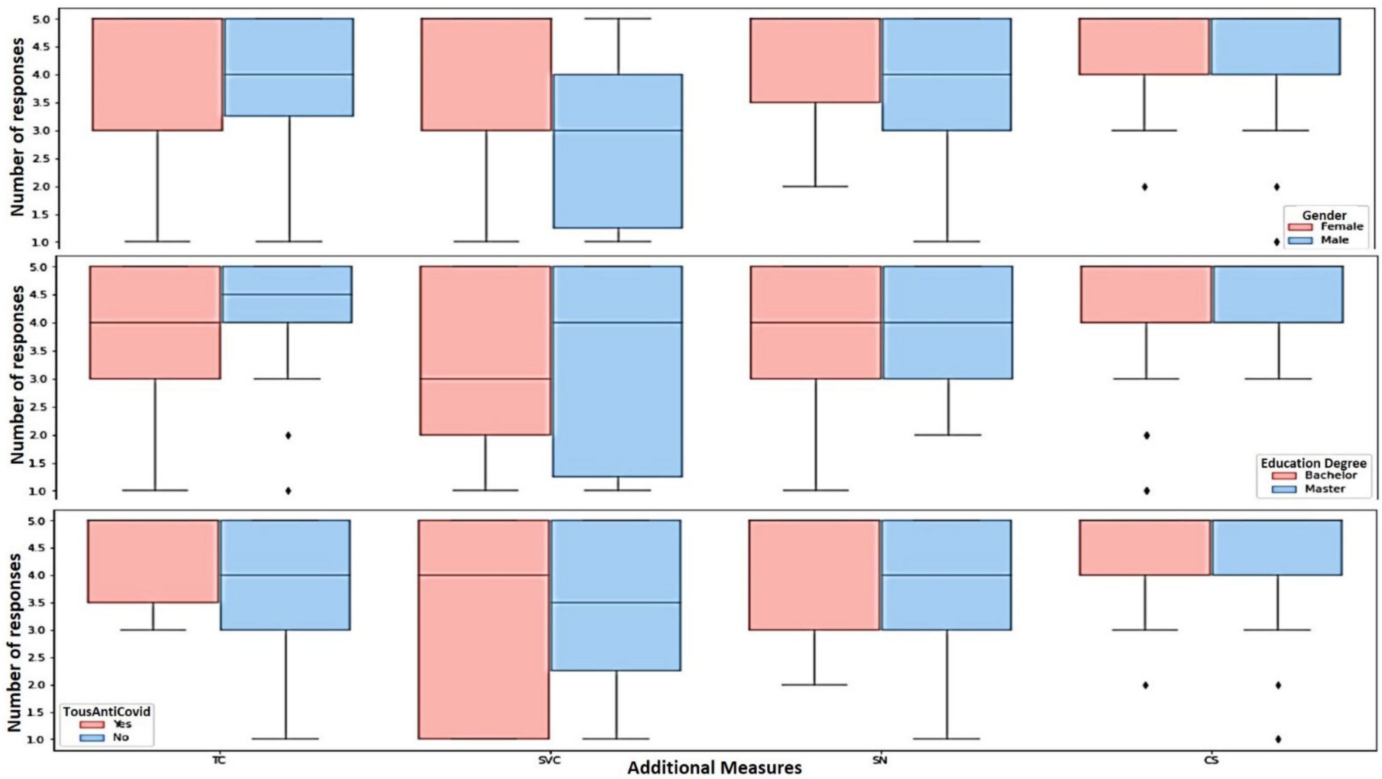

Figure 7. Influence of students' profiles on their opinions about additional safety measures.

The level of education grouped box plot shows that master's degree students cared more than bachelor's degree students about additional measures. The median seemed similar for SN (4) and CS (5) in both degrees, but it differed for SVC and TC. The median weight was more pronounced for SVC (bachelor: 3, master: 4) than TC (bachelor: 4, master: 4.5). This result shows that master's and bachelor's degree students had approximately the same judgment about SN and CS. The assessment differed between them for TC and SVC. This was particularly the case for SVC, where the responses were highly scattered among different scales.

Students using the TousAntiCovid application were more supportive of applying TC and SN than other students. In total, 5% of students using the mobile application suggested that they "disagree" with the SN implementation, while 21% of other students suggested that they "disagree" with this measure. For CS, the respondents' concentrations were around the median (5) for both groups.

4. Improvement of Anti-COVID-19 Measures

The improvement of anti-COVID-19 measures is based on the analysis of students' evaluation and suggestions. The improvement concerns measures with low rating scores, additional measures with high scores, and extensive use of BIM and smart technology. Figure 8 summarizes the methodology followed to improve the anti-COVID-19 measures. The BIM model was used to: (1) assess the physical distancing in CS; (2) check the spaces' capacities; (3) evaluate the anti-COVID-19 measures; (4) design new space configurations with enhanced safety measures.

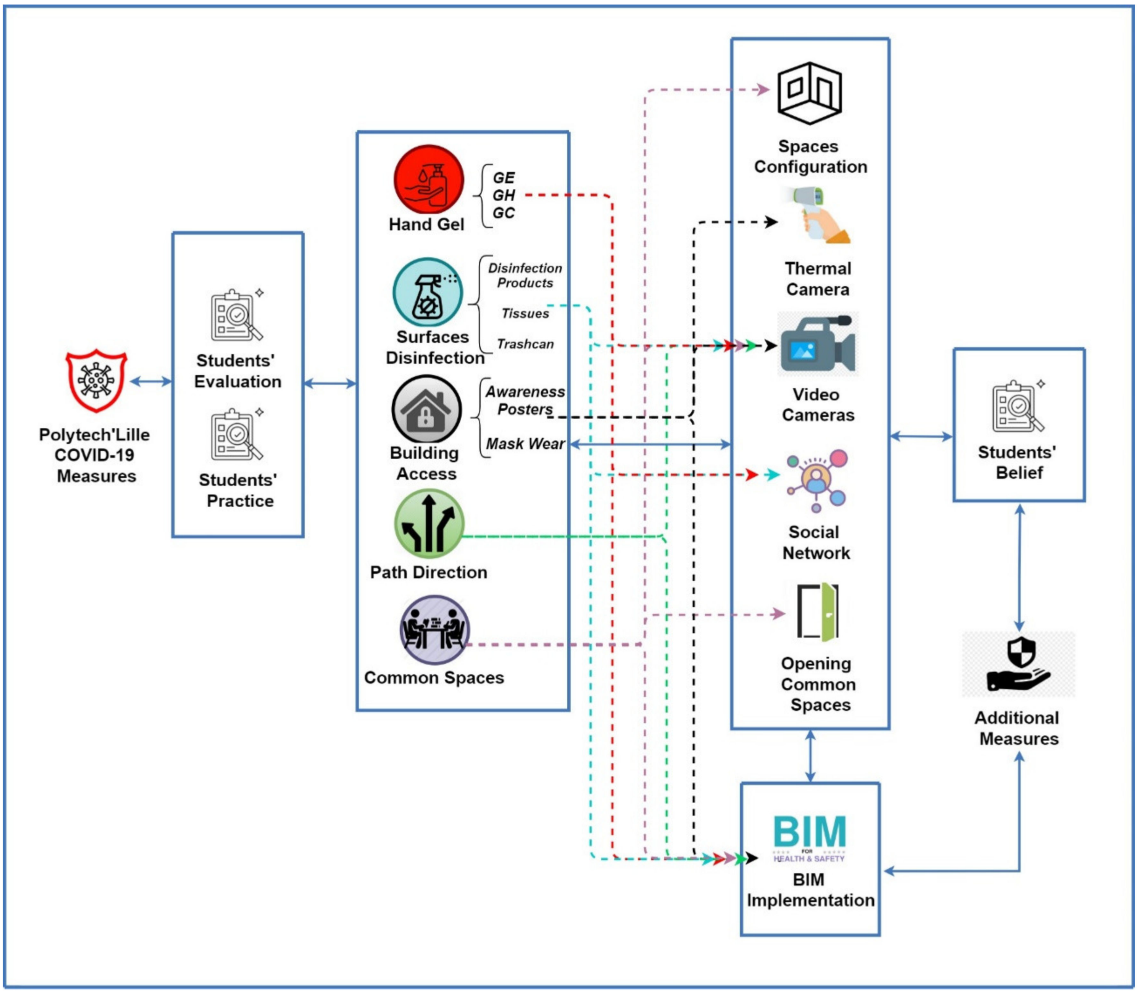

Figure 8. Methodology to improve anti-COVID-19 measures.

The optimization of the classroom capacity was conducted using the Open BIM COVID-19 (OBC-19) application, which complies with safety COVID-19 regulations stated by governments worldwide [58]. Table 6 summarizes the results of the use of this application in some classrooms. It could be observed that the capacity of some classrooms could be increased by 30%. Figure 9 illustrates the change in the desk configuration according to the OBC-19 application. The desks were redistributed in a way that respects the SD.

Figure 10 shows the improvement in measures related to hand sanitizers, DP, tissues, and trashcans. Hand gel dispensers should be available at the school entrance, in the hall, and in classrooms. Some students suggested providing masks and gloves. The three safety components were placed at the gate in the new BIM design. GH was improved by placing the hand gel dispensers at specific locations (e.g., next to the elevators, coffee machines, and vending machines). The measures are placed on each door for rooms with two doors to remind students to disinfect surfaces before and after the class and use hand gels frequently.

Table 6. Classroom capacity improvement using the BIM (OBC-19) application.

Rooms	Initial Capacity	Capacity According to Anti-COVID-19 Measures	Optimized Capacity Using BIM (OBC-19)	Increase in the Capacity (%)
Amphi LeBon	120	60	60	0
A 203	32	15	20	33
A 207	42	18	21	17
A 209	60	32	32	0
A 211	59	26	28	7
A 306	22	13	15	15
A 319	68	49	24	29

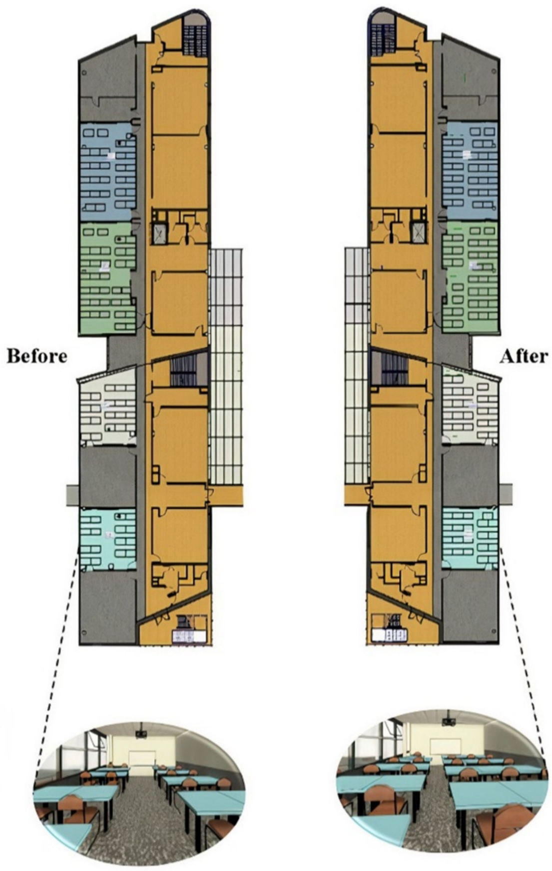

Figure 9. Architectural rooms configuration before and after BIM implementation.

The school postured some anti-COVID-19 instructions. Unfortunately, awareness posters were not well distributed in the hall. Consequently, we cleverly placed the boards (at the entrance and next to the stairs) to remind students about anti-COVID-19 measures. The general awareness advice includes the interpersonal safety distance, how they should wash their hands, avoid touching their faces, recommendations when coughing and sneezing, and the obligation to wear masks. In addition, some indications were located to inform the students about the facilities' capacity and guide students in their directions. The awareness instructions were also placed in corridors and on classroom walls to remind the students about safety measures, even during classes.

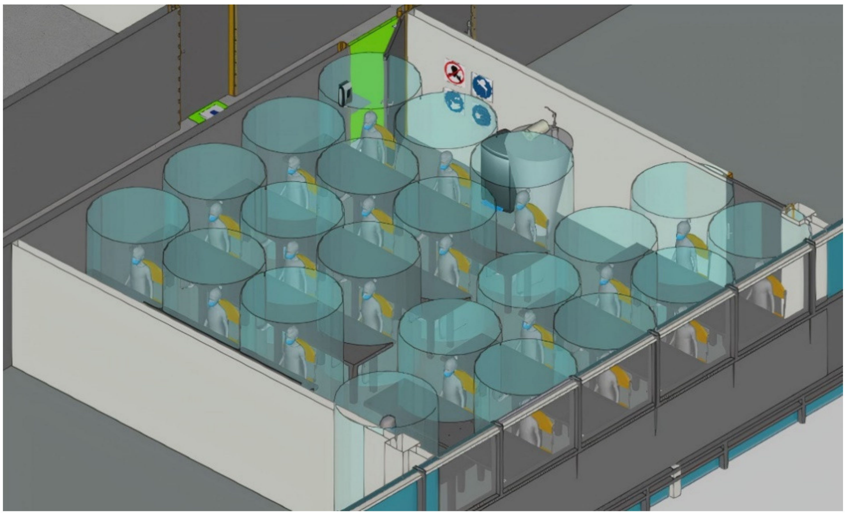

Figure 10. Improvement in Anti-COVID-19 measures.

A new indoor circulation plan was proposed because about 50% of the students were unsatisfied with the PD organization. Polytech'Lille hall signs were limited to specifying the entrance and exit doors, stairs way, and physical distancing signs for the vending machines' area. The improvement included path planning for hall circulation (two-way directions) to reduce students' crossing and gathering. Queue distance marks were used to provide a physical distancing of 1 m at crowding places such as WCs and vending machines. Figure 11 illustrates the hall architecture layout after the optimal BIM-based design for COVID-19 spread mitigation.

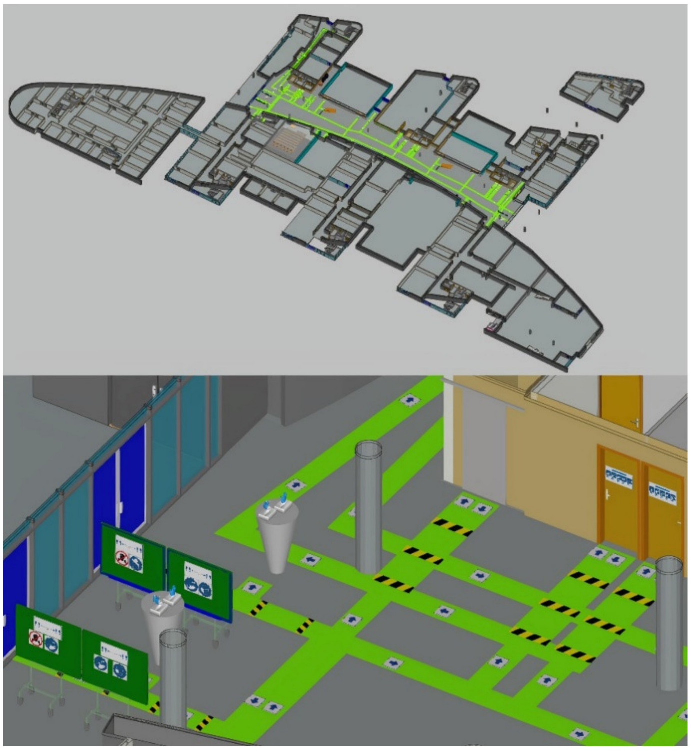

Figure 11. Entrance architecture safety layout after the optimal BIM-based design for COVID-19 spread mitigation.

5. Recommendations for Additional Measures

This section presents an analysis of the students' opinion about the digital extension of anti-COVID-19 measures, including the use of TC at the school entrance and SVC in the shared space as well as the creation of a students' SN to share information, awareness, and suggestions to improve both the safety and a collective life in the COVID period.

5.1. Thermal Camera

Fever is one of the initial and most common symptoms of the COVID-19 virus. Temperature screening has become a powerful COVID-19 detection tool [59]. In total, 73% of students suggested that they "agree" to "strongly agree" with the use of TC at the building entrance. However, this use is not sufficient to detect COVID-19 positive cases, especially for individuals between 18 and 25 years. In addition, around half of infected persons are asymptomatic [60]. A survey of 84 COVID-19 patients with a median age of 21 showed that 83% of patients did not exhibit fever, and 11% exhibited fever during one day [61]. Other limitations are related to TC devices that contribute to false values, in particular: (1) the necessity of a calibration process; (2) the correlation between facial skin and core temperature; and (3) the influence of the site environment [62].

5.2. Surveillance Cameras

SVC is helpful to check students' respect towards safety measures in real-time. Closed Circuit Television Camera (CCTV) can monitor the following safety measures: wearing masks, physical distancing, hand gels and DP use, indoor circulation paths, and room occupancy numbers. CCTV should be installed in different spaces: building entrances, shared spaces, and circulation areas. Besides, CCTV could be oriented to hand gels and DP to identify refilling needs. Only half of the students suggested that they "agree" to "strongly agreed" with SVC use, even without facial recognition.

According to French regulations, cameras in an educational institution are limited to the building entrance and circulation areas. The law protects individual privacy [63]. Access to videos is allowed to authorized people only in case of an incident check. Authorized people must be trained in using video surveillance systems [64,65]. Therefore, the SVC access to check students' practice for safety measures is still unauthorized.

5.3. Social Network

In total, 68% of students suggested that they "agree" to "strongly agree" to implement an anti-COVID-19 SN. This network will enable students to (1) interact between them; (2) identify COVID-19 positive cases; (3) share news about the COVID-19 situation; (4) optimize the use of the school facilities; and (5) share suggestions about improving anti-COVID-19 measures.

6. Conclusions

This paper presented a comprehensive methodology for evaluating and improving the anti-COVID-19 measures in higher education establishments. This methodology combined BIM and questionnaires to collect students' feedback about the safety measures and suggest improvements. This methodology was applied at the engineering school Polytech'Lille in the North of France.

The main results of this research could be summarized as follows:

1. The integration of the anti-COVID-19 measures in the BIM model allowed the school administration to access the totality of the safety measures to check their compatibility in a 3D graphical environment. The use of BIM allowed an extension of the capacity of some classrooms while respecting safety measures. The capacity of some classrooms was increased by about 30% (Table 6). The indoor circulations paths were improved using both the students' evaluation and the BIM Model (Figure 11).
2. The use of the questionnaire proved to be efficient to collect students' feedback about the safety measures and their commitment to these measures. It also allowed

collecting data about the students' suggestions to improve the safety measures. The questionnaire provided information about the students' commitment to implemented safety measures (Figure 5) and their opinion about additional digital safety measures (Figure 6).

3. Data analysis showed a higher commitment of students to disinfection measures than to access safety measures. The highest students' commitment concerned hand sanitizers, while the lowest commitment concerned the respect of imposed PD (Figure 5, Table 4).
4. Concerning the additional safety measures, students supported common spaces reopening, using TC at the school entrance, and creating an anti-COVID-19 SN. Still, they did not support the use of SVC (Figure 6, Table 5).

In future studies, the number of students participating in the survey should be increased to refine their assessment of anti-COVID-19 safety measures and their suggestions to improve these measures.

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