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Discrete-event simulation study of a COVID-19 mass vaccination centre

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ABSTRACT

The global spread of COVID-19 and the declaration of the pandemic status made by the World Health Organization (WHO) led to the establishment of mass vaccination campaigns. The challenges posed by the request to immunise the entire population necessitated the set-up of new vaccination sites, named Mass Vaccination Centres (MVCs), capable of handling large numbers of patients rapidly and safely. The present study focused on the evolution of MVC performances, in terms of the maximum number of vaccinated patients and primary resource utilisation ratio, while involving statistics belonging to the patient dimension. The research involved the creation of a digital model of the MVC, using the Discrete-Event Simulation (DES) software (FlexSim Healthcare), and consequent what-if analyses. The results were derived from the study of an existing facility, located within a sports centre in the province of Bergamo (Italy) and operating with an advanced MVC organisational model, in compliance with the national anti-SARS-CoV-2 legislation. The research provided additional evidence on innovative MVC organisational models, identifying an optimal MVC configuration. Besides, the obtained results remain relevant for countries where a significant portion of the population has not yet addressed the emergency, either for upcoming vaccination treatments. Furthermore, the methodology adopted in the present article proved to be a valuable resource in the analysis of the healthcare processes.

1. Introduction

The global spread of COVID-19 led the World Health Organization (WHO) to declare pandemic status and urge the development of vaccines against the virus [1–3]. As a result of the authorization of the first anti-COVID-19 vaccines [4], a mass immunisation plan was initiated. In Italy, the provision of vaccines started from the health care personnel and other limited population categories [5] in conventional sites, already equipped for the execution of regular vaccination activities. The challenges posed by the request to immunise the entire population necessitated the set-up of new vaccination sites: non-healthcare structures were identified as examples of high-volume and high-speed settings, that prioritize large numbers of people rapidly and safely. These structures, involving parking lots, schools, auditoriums and sports centres, are defined as Mass Vaccination Centres (MVCs) [6,7] and are organized to guarantee the performance of vaccination operations. Commonly, the flow of activities is structured in admission, administrative acceptance, medical evaluation, vaccination, monitoring and exit.

Drive-through MVCs consist of vaccination campaigns organised in parking lots, where the patients, seated in their vehicles, move through all the phases of the vaccination process. These settings were well explored in literature, both from the past epidemics’ perspective [8–10] and the COVID-19 perspective [11–14], and demonstrated to deliver vaccines in a rapid and safe way, minimizing physical contacts. In terms of operations, the organization of drive-through MVCs is similar to the one of the non-healthcare facilities that were converted into immunisation sites: operations are distinguished in arrival, acceptance, medical evaluation, vaccination and departure. Still, in drive-through MVCs, it is unclear how the post-vaccination monitoring phase with the treatment of the side effects is tackled, thus, necessitating further studies. Great attention was paid to the vaccination processes that take place in schools and auditoriums [15–19]. These settings tend to be small and decentralized, allowing the population to reach the vaccination site easily. However, spacing and ventilation are not always prioritized. On the other side, anti-SARS-CoV-2 MVCs set-up in stadiums and sports centres are examples of high-volume and high-speed settings, that prioritize physical distancing. Nonetheless, these solutions were not emphasised nor deepened in literature.

Despite the popularity of mass vaccination campaigns, the organisation of MVCs is not uniquely structured in terms of operations and physical layout. Considering the Italian legislation, defined at national [20,21] and regional level [22], the regular performance of the anti-
COVID-19 immunisation process consists of five activities: reception and administrative acceptance, medical assessment, waiting, vaccination and monitoring. Nevertheless, the lack of specific indications in the guidelines led to a certain grade of variation at the local level, thus providing additional evidence on new MVC organisational models [23–25]. For instance, the vaccination-islands model [23] redesigned the conventional MVC layout and brought medical assessment workstations and inoculation workstations close to decrease patient travelling between the two separate activities, rationalising timings.

Hence, the present study aimed at extending the available scientific data on anti-SARS-CoV-2 MVCs, by studying a facility that operates with an advanced organisational structure: the phases of medical assessment and vaccination were joined together and performed in the same location, with the objective of improving the performance of the MVC by ensuring high-quality standards. The evolution of the MVC behaviour was analysed while changing its critical parameters, like the number of active vaccination workstations, the number of active registration and acceptance workstations and the number of people entering the system. The pursued methodology consisted of a Discrete-Event Simulation (DES), able to virtually replicate the processes of a real-world system as a discrete series of events over time. FlexSim Healthcare was the selected software-package and it is completely dedicated to medical environments. The software was successfully adopted in distinct healthcare challenges [26–28], demonstrating the capability to handle the anti-

Fig. 1. Main patient flow of the mass vaccination process.
SARS-CoV-2 MVCs analysis too. Experiments were conducted on an existing MVC for the prevention of SARS-CoV-2 infections, established within a university sports centre in the province of Bergamo. At the time of the analyses, the facility was serving first, second and third doses, planning to be the reference point for the delivery of the fourth doses too.

2. Methodology

2.1. Vaccination centre process

The mass vaccination process under examination was conceptualized as a set of five macro-activities: entrance, reception and administrative acceptance, medical assessment and vaccination, monitoring and leaving. The immunisation process begins when the patient arrives at the outdoor entrance, where a first checkpoint station is located. There, an operator is responsible for managing the incoming flow of patients and verifying the reservations. Then, the patient walks down a pathway leading to an outdoor area, enclosing two sanitization spots and the outdoor waiting area. The patient is subjected to rapid sanitization and waits his turn in a waiting area organised according to the dose of inoculated vaccine. An operator responsible for the temperature control determines the access to the facility and, in particular, the reception and administrative acceptance area. Each workstation is handled by a clerk whose role consists of recording the patient’s administrative data, issuing an alphanumeric code and guiding the patient to the subsequent activities. The patient reaches the appropriate waiting area and waits until his alphanumeric code appears on the digital screens. Then, the patient goes to the proper inoculation workstation, where a doctor and a registered nurse are in charge to execute the medical assessment and vaccination, respectively. The two activities are performed simultaneously: the doctor collects the pre-vaccination medical history and informed consent, while the registered nurse prepares the equipment and executes the inoculation. An additional waiting period for surveillance of vaccinated patients occurs. The person stays in the monitoring area and, if no adverse reaction arises during the waiting period, he is allowed to exit the process. Otherwise, the waiting in the monitoring area is being extended.

The average mass vaccination process under investigation was conceptualized using the BPMN graphical representation. Besides, variations from the ordinary activities were observed throughout the entire process. Although unusual, the patient might be unable to continue the vaccination pathway due to inadequate temperature (at the entrance) or inadequate clinical conditions (during the medical assessment); in rare instances, the patient may have to change vaccination stations because of his ineligibility for the type of vaccine delivered by that station. All the mentioned variations were included in the development of the virtual replica of the MVC to better capture the variability of the process.

2.2. Vaccination centre modelling and simulation

Considering the physical constraints of the system (Fig. 2), a 3D virtual model was developed using FlexSim Healthcare DES software. The healthcare process was accurately replicated following the elements defining the macro-activities of the conceptualised process (Section 2.1). All structural components were represented through fixed resources. Sets of multiple location objects (chairs) represented the twelve waiting areas: two external and ten internal (eight assigned to the eight rows of vaccination stations and two linked to post-vaccination monitoring). The waiting areas were designed based on rules of distancing in closed environments and their capacity was sufficiently large to face great variations of the incoming demand. Two rows of five workstations stood for the registration and acceptance desks (R1-R10). The medical assessment and vaccination workstations, organised into eight rows of six stations, were distributed equally over the two halves of the facility and categorised with a letter, (A-H) indicating the row, and a number.
(1–48), identifying their position uniquely. For the virtual representation of the healthcare operators, task executors were involved (Table 1).

### 2.2.1. Process parameters and distributions

The resulting model consisted of the 3D interface (Fig. 3) integrated with two process flows.

The first process flow was responsible for creating flow objects (patients): the flow of patients arriving at the vaccination centre was scheduled with an equally time-spaced frequency, as access to the vaccination centre was programmed by appointment. According to the daily reports collected by the MVC structure at the time of the study, 60% of the patients accessing the structure received the third dose.

The second process flow regulated the interactions between the 3D elements: logics and activities of the vaccination process observed in Section 2.1 were digitally translated with a sufficient level of accuracy to allow a dynamic representation of the healthcare activities. The main time parameters are displayed in Table 2. The values of the registration and medical assessment and vaccination (dose 1 and dose 2/3) activities came from daily reports collected by the MVC structure under investigation: inconsistent records and outliers were discarded and the probability distributions that best represented the cleansed data set were automatically and precisely determined using FlexSim ExpertFit tool. The physical or geometric interpretation of the identified continuous time distributions is determined by three parameters: gamma (location point of the distribution’s range of value), beta (scale of measurement for the values in the distribution’s range) and alpha (distribution shape within the general family of distributions of interest). In some distributions (e.g., normal and exponential), the gamma parameter is absent. Along with the characterisation of time distribution parameters, ExpertFit provided an indication of the sampling error (Table 2). Furthermore, the goodness-of-fit of the fitted distributions was confirmed through a Chi-Square test (Table 3).

The time information of the reservation check, sanitization, temperature check and monitoring activities came directly from semi-structured interviews with the MVC administrative experts. The

### Table 1

| Role of the task executor | Number of task executors | Position of the task executor |
|---------------------------|--------------------------|-------------------------------|
| Reservation controller    | 1                        | Outdoor entrance              |
| Temperature controller    | 2                        | Facility entrance             |
| Registration clerk        | 10                       | Registration station (R1-R10) |
| Registered nurse          | 48                       | Vaccination station (A1-H48) |
| Physician                 | 48                       | Vaccination station (A1-H48) |

### Table 2

| Process activity                     | Time distribution (parameters) [s] | Sampling Error [s] |
|--------------------------------------|------------------------------------|--------------------|
| Reservation check                    | Normal (7.00, 2.00)                |                    |
| Sanitization                         | Deterministic                      |                    |
| Temperature check                    | Deterministic                      |                    |
| Administrative acceptance            | Lognormal2 (6.50, 20.00, 0.60)     | 0.07 – 0.23 %      |
| Medical assessment and vaccination (dose 1) | Invertedweibull (39.50, 170.30, 2.50) | 9.52 – 3.38 %     |
| Medical assessment and vaccination (dose 2/3) | Loglogistic (41.30, 84.50, 2.60)    | 2.51 – 1.68 %     |
| Monitoring                            | Exponential (900.00, 1.00)          |                    |
| Monitoring (presence of adverse events) | Exponential (1200.00, 1.00)        |                    |

### Table 3

| Process activity                     | Statistic test | Critical value for level of significance |
|--------------------------------------|----------------|----------------------------------------|
| Administrative acceptance            | 11.23          | 0.10 21.06 23.69 29.14                 |
| Medical assessment and vaccination (dose 1) | 8.34          | 0.05 13.36 15.31 20.09                 |
| Medical assessment and vaccination (dose 2/3) | 14.76         | 0.01 18.55 21.03 26.22                 |

Fig. 3. 3D Simulation model of the mass vaccination centre.
collected data converged into the distribution’s values reported in Table 2 and their appropriateness was further verified by experienced medical personnel, responsible of these processes on a day-to-day basis. Note that the time values belonging to the sanitization and temperature check activities were assumed to be deterministic as these tasks, given their automation, were not subjected to randomness.

Along with the main activities reported in Table 3, the second process flow included additional activities generating alternative sub-processes to the primary vaccination pathway. The frequency of these tasks was determined in accordance with the workers of the MVC under investigation and was extremely low.

### 2.2.2. Process performance measures

The performances of the mass vaccination system, as well as patient statistics, were evaluated through process performance indicators (KPIs). The primary performance measure was the MVC productivity, measured as the maximum number of patients treated by the healthcare facility daily. Productivity was also measured in relation to the number of active vaccination stations, resulting in the productivity indicator of each vaccination site. Productivity involved the average utilisation rate of the vaccination workstation, defined as the time dedicated to medical assessment and vaccination activity over the workstation total available time. Conceptually, this indicator represented an approximate measure of the utilisation percentage of the operators working within the vaccination workstation. Additional performance measures regarded patient dimension.

### 2.2.3. Process validation

The adequacy of the simulation model with respect to the intended application was assessed during the validation phase. The virtual model representing the vaccination processes of a mass vaccination centre underwent an initial qualitative validation (face validity) [29]: health workers with distinct professional roles confirmed the correctness of the representation of the vaccination process, viewed in terms of conceptual and virtual translation. Also, performance results and patient statistics were considered reasonable, thus validating the model subjectively. A subsequent quantitative validation [29] was performed: a model, appropriately fed with information coming from a specific working day, was developed and compared to the observable system using statistical tests. The selection of the parameter for the validation analysis fell on an

#### Table 4

| Validation parameter | Real data [s] | Simulation data [s] | p-value |
|----------------------|--------------|---------------------|---------|
| Average waiting time for vaccination workstation availability | 247 | 213 | 0.165 |

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Fig. 4. Productivity indicators. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article)
element, whose values were not provided as input to the modelling task: patient waiting between the registration phase and the medical assessment and vaccination phase. In particular, the patient waiting data obtained from the simulation was compared to the actual waiting data collected on that specific day. The \( p \)-value obtained from the analysis of variance (ANOVA) (Table 4) showed no statistically significant difference between the developed model and the real system, thus validating the model objectively.

3. Results and discussion

Multiple simulations of the mass vaccination process over a single
working day (12 h, run time) were conducted respecting the operating conditions of the considered facility. The simulation of a single standard vaccination day was possible due to the fact that the MVC operated 7 days a week, without distinction on weekdays and weekends (the condition was tested by analysis on long-term data). Simulation runs were iterated four times, ensuring the possibility to capture consistent results and returning outputs described by average values (95 % confidence interval) and standard deviations.

The initial simulations (Fig. 4) examined the productivity of the system. Fig. 4a reports the maximum number of patients able to be processed for each level of active inoculation stations, ranging from a minimum of 10 sites to a maximum of 40. Specifically, the number of active vaccination stations was allocated following the operating conditions dictated by the MVC structure under investigation, namely, the allocation of stations in proportion to the scheduled type of vaccine dose (60 % of patients performed the third dose, while the remaining 40 % were divided into first and second dose). As a result, out of 10 active vaccine stations, 4 were allocated to the first and second dose, while 6 were allocated to the third dose. Considering the mentioned percentages of scheduled vaccination doses and the MVC working conditions, the increase in active inoculation stations occurred by multiples of 5: 1 station dedicated to the first dose, 1 to the second dose and 3 to the third dose. Depending on the number of active vaccination stations, the facility immunised between one thousand and three thousand people daily. Moreover, the rate of patients processed per vaccination site reported a performance reversal. Growing gains were observed by increasing the number of active inoculation sites up to 20, while decreasing gains were detected by overpassing it. Additionally, a reduction in productivity rate was detected expanding the accessibility of vaccination sites beyond 35 inoculation sites.

The average utilisation rates of vaccine sites dedicated to the third dose are plotted in Fig. 4b and confirmed the productivity trend (processed patients per vaccination site, Fig. 4a). In fact, considering the four efficient scenarios (coloured markers), the utilisation rate increased up to the point of performance reversal point, beyond which, it decreased. The utilisation rates of the vaccination station dedicated to the delivery of third doses differed widely for the four efficient scenarios: going from a minimum of 59 % to a maximum of 82 %. The non-utilisation of the inoculation station might be attributable to several events, such as the sanitisation activity that takes place between the vaccination of a patient and the following one and the patient travelling to reach the inoculation station. In addition, the inactivity was also caused by the absence of a patient when the workstation was actually available, occurring especially at the beginning (8.00 − 9.00 am) and ending (7.00 − 8.00 pm) phases of the process. Moreover, these events might also be dictated by system inefficiencies, such as the lack of logic in guiding patients to less saturated vaccine lines.

Patient statistics are reported in Fig. 5. Patient stay time within the facility is represented in Fig. 5a, presenting a value of 25 min approximately for the efficient scenarios involving more vaccination resources. The configuration involving less vaccination stations presented a slightly longer patient stay time, exceeding 27 min. For the same level of active vaccination sites, almost no difference in terms of the average patient length of stay was recorded between the under-saturated scenarios (points fed by a fewer number of input patients and located prior to the efficient scenario) and the efficient scenario (coloured markers). Consequently, exceeding the efficient scenario, the patient stay time tended to increase with a linear trend. Therefore, the efficient MVC settings could be reached without negatively impacting on patient metrics: first and foremost, patient stay time. In contrast, using a number of vaccine resources that exceeded the one defined by the efficient scenario, a fraction of the patients accessing the process did not complete the pathway and, simultaneously, the patient statistics worsen in a considerable way, impacting the quality perception of the service provided. Fig. 5b reported the information on stay time dispersion for the four efficient scenarios (coloured data): as the number of active vaccine sites increased, there was a gradual growth in the dispersion of stay time data and in the likelihood of patients staying in the facility for a longer time. Actually, the progressive elongation of the right tail for the efficient configurations still corresponded to modest stay time values.

Fig. 5c explores the composition of the patient stay time variable, partitioned into receiving direct care (e.g., medical assessment and vaccination), receiving indirect care (e.g., non-healthcare activities) and idleness. Depending on the number of active vaccine sites, the average idle time varied from 22 % to 35 % of the stay time value of the efficient scenarios. Idle was prompted by two main causes: waiting (e.g., waiting for the registration or medical assessment and vaccination tasks) and travelling to the different locations within the system (e.g., movement for reaching the outdoor waiting room from the reservation control station). Waiting represents pure waste: the inactivity related to the outdoor waiting area was negligible, while the inactivity related to the indoor waiting area was between the 13 % and 27 % of the stay time value for the efficient configurations. Travelling may be considered as an unavoidable non-value-added activity in the immunisation process and its value must be minimised by simplifying trajectories and preventing unnecessary motion. Given the physical design of the MVC, patient trajectories were already set up to perform all healthcare activities while minimising motions. Travelling time of the efficient configurations varied between 8 % and 10 % of the average patient stay time. Hence, the outcomes further validated the adoption of the efficient scenarios, showing that the portion of patient inactivity was adequate and sustainable when compared to its total length of stay.

The MVC optimal configuration, identifiable as the system design able to process the maximum number of patients given the same number of active vaccination sites while maintaining suitable patient metrics, was characterised by 20 active vaccination workstations. Statistics are summarised in Table 5.

As shown in Fig. 6, additional simulations were conducted on the optimal configuration. Sensitivity analyses assessed the impact, in terms of processed patients and patient stay time, of varying the length of the patient arrival period (Fig. 6a) and the number of active acceptance and registration stations (Fig. 6b).

The MVC access time period that ensured to process within the scheduled time all patients entering the healthcare service (equally spaced in time, between 8.00 am and 7.00 pm), was computed and found to be equal to a single interval of 11 h. Extending the length of the access time by one hour (until 8.00 pm), 3 % of the input patients were not treated as these patients would end their vaccination process beyond the operating time of the MVC. Reducing the variable by one hour (until 6.00 pm) made possible to treat all 100 % of the input patients, however the stay time of the patients increased considerably. This latter variation impacted on the stay time of just a portion of patients, as evidenced by the dispersion increase. In fact, unlike patients entering at the beginning of the day, those who access the facility in the late afternoon experienced an extension of their stay. Besides, strategies that include splitting the length of the access time into multiple intervals did not lead to improved results.

The impact of changing the number of active registration stations was investigated: activating fewer than 6 registration stations avoided

| Table 5 |
| Simulation KPIs and patient metrics of the optimal configuration, 20 active vaccination workstations. |
| KPIs |  |
| Processed patients | 2921 patients |
| Avg. processed patients per vaccination site | 146 patients / site |
| Avg. patient stay time | 24.73 min |
| Avg. patient idle time | 5.61 min |
| Avg. patient moving time | 2.35 min |
| Avg. patient waiting for vaccination site time | 3.26 min |
| Avg. utilisation of the D3 vaccination site | 9.84 h/day |
executing all the patients accessing the system and affected patient metrics negatively. The use of 6 or more registration stations allowed to treat 100 % of patients in input to the process. Moreover, moving from 6 to 10 acceptance stations, a detectable reduction in the patient length of stay was recorded.

Lastly, a system blockage that prevents the vaccination process from running properly was tested in Fig. 6c: the block was conceived as an interruption of the crucial healthcare activities (e.g., registration, medical assessment and vaccination), characterised by 4 different durations (15, 30, 45 and 60 min) and 4 different times of onset (8.00 am, 11.00 am, 2.00 pm and 5.00 pm). During this event, the patients kept accessing the system, positioning themselves in the external waiting area. The MVC system reacted positively to the 15-minute and 30-minutes block, by treating 100 % of patients in almost all the simulations. Although MVC systems with 45-minute and 60-minute blocks were able to vaccinate large numbers of patients entering the process (at least 99 % and 97 % of input patients, respectively), they exhibited the first difficulties.

Fig. 6. Additional simulations.
4. Conclusion

The present article aimed at extending the available scientific evidence on anti-SARS-CoV-2 MVCs, leveraging on an existing facility located within an Italian university sports centre. The study was conducted by means of simulation experiments on a digital model of the MVC, using FlexSim Healthcare software, in combination with sensitivity analyses. The performance evolution of the MVC, measured in terms of the maximum number of vaccinated and utilisation rate of the vaccination workstation, was assessed while modifying the most important parameters. Special considerations were given to the patient dimension.

Furthermore, for MVCs comparable to the one described in the current document, an optimal configuration was defined. Activating 20 active inoculation sites, managed by 20 physicians and 20 registered nurses, the facility processed a total of 2921 patients daily with a ratio of processed patients per inoculation site which was maximum and amounted to 146. The considered configuration involved the activation of only 41 % of the available vaccination resources, underscoring that the 48 vaccination sites were oversized compared to the efficient operating conditions of the facility. Nevertheless, the percentage also suggested the likelihood of achieving efficient results with a fair number of resources, bearing in mind that medical operators are scarce resources. The utilisation rate of the vaccination workstations dedicated to the inoculation of the third doses reached an elevated level, on average amounted to 82 %. The inactivity of the vaccination resource was attributable to sanitation activities, patient time to reach the vaccination site from the waiting area and, lastly, system inefficiencies. To further minimise this latter, it is critical to design real-time systems guiding patients to less saturated vaccination lines. On behalf, the utilisation rate of the vaccination resources should be further investigated to not overburden the healthcare operators. Observing patient statistics, the stay time within the facility averaged 24.73 min. Idle time, distinguishable in patient waiting times and travelling times, constituted 23 % of the overall stay time. The perceived level of idle time attested a less overcrowded system, thereby leading to higher service quality.

However, it should be noted that MVC configurations, widely divergent in terms of structural and functional conditions from the one considered, may experience different productivity and patient outcomes. For instance, different logics in terms of patient arrival rate during the day and week significantly affect patient metrics (e.g., waiting times). Future studies on this aspect would broaden the outcomes, justifying the presence of differences in comparable instances.

To conclude, the present study brought scientific evidence on the viability of vaccination processes characterized by organizational layouts which were distinct from those available in the literature and those specified by the anti-COVID-19 guidelines. The results derived from the research are particularly important for countries and institutions that, unlike Italy, are characterized by a low level of vaccine cycle completion; in fact, being able to leverage from the very beginning on an optimized organizational layout with a sufficient, but minimum number of healthcare resources, favours a rapid and effective mass immunisation program. Also, the findings are adequate in facing comparable and future epidemics, driving researches towards the development of innovative and improved mass vaccination models.

Lastly, the study and analysis of the mass vaccination processes demonstrated to be successfully performed through the methodology proposed in the current article. Indeed, the execution of a simulation study by means of a dedicated DES software allowed the analysis of a specific healthcare process: the mass vaccination campaign. Besides the possibility of gaining knowledge about the normal operation of a healthcare process, this methodology allowed for the investigation of alternative strategies, without committing resources for their implementation. Therefore, the result deriving from the execution of the current methodology broadened the scope of application of the DES techniques in the healthcare field.

CRediT authorship contribution statement

Francesca Sala: Software, Validation. Gianluca D’Urso: Conceptualization, Methodology, Supervision. Claudio Giardini: Conceptualization, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Summary points

- The global spread of COVID-19 and the establishment of mass vaccination campaigns required the set-up of specific vaccination sites, known as Mass Vaccination Centres (MVCs), capable of handling large numbers of patients rapidly and safely.
- Multiple and different MVCs physical layouts and organizational structures are present, leading to a certain grade of variation in the execution and performance of the vaccination process.
- The present study provided evidence on the efficiency of the vaccination campaign within a sports centre, operating with an organizational layout distinct from those available in the literature and those specified by the anti-COVID-19 guidelines.
- The work outlined a methodology, based on DES tools and techniques, for the study and analysis of healthcare processes.

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