Proceedings of the 2022 Winter Simulation Conference
B. Feng, G. Pedrielli, Y. Peng, S. Shashaani, E. Song, C.G. Corlu, L.H. Lee, E.P. Chew, T. Roeder, and P. Lendermann, eds.

SIMULATION MODEL FOR PLANNING DENTAL CARIES PREVENTION AT THE REGIONAL LEVEL

Maria Hajłasz
Bożena Mielczarek

Faculty of Management
Wrocław University of Science and Technology
ul. Ignacego Łukasiewicza 5
Wrocław 50-371, POLAND

ABSTRACT

Dental caries is a disease of the 21st century. The best way to prevent this is to implement preventive programs. In planning such programs, it is important to select a configuration of services that will arrest dental caries, but also remain within the resource capabilities of the relevant regional authorities. The aim of this paper is to present a discrete event simulation model to test different scenarios of dental caries prevention addressed to children in a sample school in Southwest Poland. We developed and tested three scenarios which involves a different configuration of preventive services. The first scenario assumes fluoridation only, the second scenario assumes fluoridation, dental check-up and sealing, and the third scenario assumes all of the previous ones, plus education. By conducting simulation experiments, it is possible to select the third scenario which allows good results in the oral health of students, while using resources at a level that does not exceed the full-time annual employment in Poland: 491.7 and 285.9 h per year for dentists and nurses, respectively.

1 INTRODUCTION

Dental caries is one of the most prevalent diseases in Poland and worldwide. Despite increasing health awareness among the population and improving access to medical care, dental caries affects more than half of the world's population (World Health Organization 2017). It is a multifactorial disease and it is impossible to identify a single cause (Mathur and Dhillon 2018). Disease progression may result from, for example, individual health predispositions, the environment, hygiene and dietary habits, or behavior that is supportive, such as the frequency of tooth brushing. However, this can be effectively prevented by taking complex actions. The prevention of dental caries, compared to treatment of the possible consequences of the disease, is cheaper and less painful. Prevention can be carried out individually in dental offices, but on the scale of caries, it does not provide sufficient results. Group preventive services implemented in the early years of life have already been noted to provide measurable benefits in caries prevention. Therefore, increasing attention is being paid to the preventive programs implemented in schools.

Various available methods and tools, such as analytical ones, namely: algebra, differential calculus, or linear programming theory, can be used to support decision-making in healthcare. These methods are very detailed, they are usually applicable to relatively simple systems that are not subject to frequent and random changes. Simulation methods are an alternative to analytical ones. The use of simulation modelling in healthcare is justified owing to the complexity, uncertainty, randomness, and dynamic relationships between different elements. Simulation enables individual attributes, such as age, sex, health status, or

978-1-6654-7661-4/22/$31.00 ©2022 IEEE

medical history to be assigned to each patient (Zhang 2018). From a management perspective, it allows for easy and intuitive communication of results to decision-makers. In addition, it is possible to experiment with the model of a given system without incurring the real consequences of any decisions taken (Eldabi et al. 1999).

In this study, the discrete event simulation (DES) approach was chosen because it allows dynamic tracking of the oral health status of students throughout their primary school education. Progression of dental caries is a dynamic process that occurs over time. Children have individual characteristics and predispositions that make them susceptible to the disease. Teeth fall out and grow at different times, and caries progresses with different intensities. Depending on the preventive services provided, it may be possible to arrest disease progression or completely avoid it. Therefore, methods that, among others, enable observation of changes in students' oral health as time progresses are especially applicable here. Considering the features of the DES method, we believe that it will perform well in the present study. No articles were found that addressed the issue of planning preventive care in schools using simulation modelling. Therefore, the contribution of this work not only supports decision-making processes in this area of healthcare policy planning at the regional level, but is also valuable for future research in this field.

This study focuses on the issue of supporting dental caries prevention care planning in schools located in one of the cities in Southwest Poland. The objective of this study is to present a DES model to enable the selection of an acceptable scenario for a caries prevention program targeting school-aged children. We examined the configuration of preventive services and human resources the pupils would graduate with oral health goals. Undoubtedly, the most effective solution to the caries problem is to provide children with unlimited access to specialists and preventive services. However, the resources and capabilities of regional governments in providing such care are limited. Therefore, we investigated the configuration of preventive services pupils would graduate with the lowest possible average caries rate and the use of human resources. The multifaceted nature and different impacts of the same services on different students depending on their different predispositions make tools that capture the stochasticity needed to test different scenarios in dental caries prevention programs. This work is part of a larger study that focuses on various aspects of supporting preventive care planning for dental caries using simulation modelling (Hajłasz and Mielczarek 2022).

2 LITERATURE REVIEW

Caries disease is caused by many factors that interact with one another. Some of these can be classified as medical, such as bacteria involved in the process of caries formation, particularly *Streptococcus mutans* (Selwitz et al. 2007). The nonmedical group included parental education, income level, and hygiene habits. Whether caries progress or arrest depends on the balance between demineralization and remineralization (Featherstone 2000). To support remineralization processes, early detection and prevention of the disease, such as fluoridation, sealing of first molars, and education are very important.

Preventive care planning for caries is a complex issue that can be considered from multiple perspectives. One may include planning preventive care with individual predispositions in mind, such as risk assessment (Jenson et al. 2007). Caries prevention strategies may vary according to the risk group. Low-risk patients generally require less professional supervision of caries. In contrast, the use of sealants may be recommended in moderate-risk patients. High- and extreme-risk patients must be aggressively managed to eliminate or reduce the possibility of a new or recurrent carious lesion.

When planning preventive care, it is important to consider which care is directed. Children with autism have greater needs and require more time and attention than do children without autism (Jaber 2011). In addition, dental care is planned differently for children (Chu et al. 2012), and the elderly (Brunton and Kay 2003). Preventive care planning is also influenced by the region in which it is delivered. In some states, care systems are public, whereas others are private. The amount of money spent on dental care varies. Wang et al. (1998) described strategies and resource allocation in terms of preventive dental care for children and adolescents in Denmark, Iceland, Norway, and Sweden.

Different methods are used to plan various aspects of healthcare. This includes the simulation methods, which are most commonly categorized into four groups: agent-based simulation (ABS), system dynamics

(SD), discrete event simulation (DES), and Monte Carlo simulation (MC) (Brailsford et al. 2009). In the context of supporting caries preventive care planning, papers using the above methods can be identified, but there are not many, and there is still a gap to fill. The SD method was used to simulate and compare the potential outcomes of nine preventive interventions and city defluoridation in disease reduction and net savings over a 10-year horizon (Edelstein et al. 2015) or to determine which interventions, individually and in combination, could have the greatest effect in reducing the experience and cost of caries (Hirsch et al. 2012). MC was used to analyze the economic impact of using the selected method (silver diamine fluoride) to prevent caries progression from the perspective of Medicaid programs compared with standard restorative treatment (Johhnson et al. 2019). DES was used to determine the optimal combinations of staffing levels and sealant stations for school-based sealant programs (Scherrer et al. 2007). From this brief overview, it appears that simulation methods have a wide range of applications, and one such area may be preventive care planning at a regional level. In addition, a further possible direction for the use of simulation approaches in the area of prevention program planning has been identified, which is the hybrid approach. The hybrid approach is already widely used in health care, and many benefits of combining simulation methods with each other or with methods from other groups, such as analytical, have been noted (Powell and Mustafee 2014).

3 STUDY DATA AND METHODS

3.1 Input Data

Access to actual data on the oral health status of schoolchildren is limited. These are medical data; however, when such data are collected, only final studies are available, but not individual data records. In the context of this study, the most important data are those related to the prevalence of caries and the effectiveness of the selected preventive services.

The present study used publicly available aggregated data describing the average number of students, by age group for 6, 7, 10, 12, and 15 years, with dental caries, primary and permanent teeth, and dmft indicators (decayed, missing, and filled teeth) (Olczak-Kowalczyk et al. 2021). This indicator is commonly used in dentistry to assess dental health. The symbols dmft and DMFT are used for primary and permanent teeth, respectively. The higher the index value, the more advanced are the caries.

Caries prevention is the result of many overlapping factors; therefore, the effectiveness of preventive services is difficult to be defined clearly. Many attempts have been made to determine the magnitude of the effects of different services on caries prevention. In the present study, the effectiveness of sealing and fluoridation was assumed based on available literature. The literature review confirmed the positive impact of education in the context of caries prevention, but it is very difficult to investigate; therefore, the literature does not provide clear answers in this context. Therefore, when certain assumptions could not be fully considered and empirically verified, they were developed in this study after a careful analysis of the available literature and consultation with dental experts.

3.2 Study Background

Education in Polish primary schools lasts nine years: kindergarten and eighth grade. Children typically start kindergarten at the age of six and graduate from school at the age of 14. The average number of students per class is 20 in Wrocław, a city located in Southwestern Poland (Statistics Poland, 2021). One of the assumptions of the health policy in Poland is to provide preventive care to students in primary schools. This was written in the Act on Healthcare for Students that came into force in 2019 (Polish Parliament 2019). The law defines, among others, the scope and objectives of pupil healthcare and its management, together with the tasks assigned to specific people. The school principal is designated as the person responsible for student access to services, and the National Health Fund is the entity that funds them. However, the problem is the lack of materials and people who provide preventive services in schools. It should also be pointed out that doctors have no reason to carry out prophylaxis at their own cost. Preventive activities should be inspired, managed, and financed by the state. Investment in the prevention of dental caries can save a lot of money because it is much cheaper than treatment, but management and planning require constant improvement.

3.3 Overview of the Model

This research is part of a larger study conducted in the area of supporting preventive care planning in schools using simulation. Hajłasz and Mielczarek (2022) collected and discussed the assumptions for building such models and presented a preliminary model concept. Based on these assumptions, a model with five main components was developed (Figure 1).

In the presented model, each student was assigned four basic attributes related to oral health: the number of primary teeth, number of permanent teeth, dmft, and DMFT. The values of the four attributes were updated at the end of each school year. It was assumed that for the seventh and eighth grades, only the indicators for permanent teeth were updated, as children no longer had primary teeth in their mouth.

For each 6-year-old student, initial values of the primary and permanent teeth were generated at the beginning of the simulation from random distributions with parameters defined based on actual data. The dental status in subsequent years was generated from fitted distributions by analyzing differences in average values and standard deviations, according to the empirical data obtained. If data were not available for consecutive life years, the next reported value was considered and then divided by the number of years in between to obtain the change value for the years immediately following life. Over time, the primary teeth fall out and the permanent teeth grow. Table 1 presents the parameter values of the normal distributions assumed in the model to represent changes in the primary and permanent teeth of the students. The parameters representing changes in the dmft and DMFT indices were elaborated in the same way as for the teeth (Table 2). If pupils develop caries in later years of life, then they have initial values calculated for the age at which the caries occur, based on actual data, and then the changes depend on when the caries occurred.

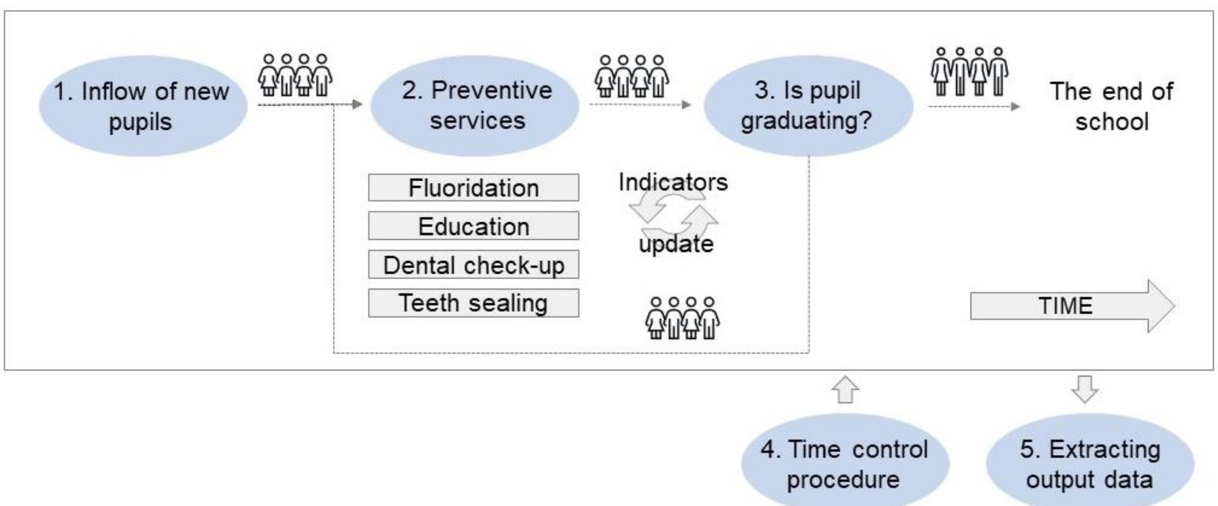

Figure 1: The DES model overview.

By the age of 10, the number of children with dental caries increased (Table 3). For years when actual data were not provided, the next percentage was taken. Between the ages of 6 and 7, dmft increases and then decreases to 0 at the age of 12 (assuming that children no longer have primary teeth in which there may be caries). In contrast, DMFT increases with increasing age. Based on the actual data, a situation in which students were not provided with preventive services was described. If preventive services are provided, their effectiveness, expressed as a percentage value, affects caries reduction. In other words, each change that leads to an increase in the dmft and DMFT indicators is reduced according to the effectiveness assumed in a given scenario. Each scenario had different configurations of fluoridation, dental check-ups, sealing, and education as preventive services.

Table 1: Normal distribution parameter (avg. – average and sd. – standard deviation) assumed in the model to calculate the initial values and changes of primary and permanent teeth in the next available years. Elaborated based on Olczak-Kowalczyk et al. (2021).

Years old	Primary teeth		Permanent teeth	
	avg.	sd.	avg.	sd.
6	17.64	1.2	4.25	2.59
6-7	2.81	0.21	4.64	0.31
7-10	10.95	0.41	10.76	0.44
10-12	3.88	0.38	5.94	0.43
12 -15	n/a	n/a	2.24	0.17

Table 2: Normal distribution parameter (avg. – average and sd. – standard deviation) assumed in the model to calculate the initial values and changes of dmft and DMFT indicators in the next available years. Elaborated based on Olczak-Kowalczyk et al. (2021).

Years old	dmft		DMFT	
	avg.	sd.	avg.	sd.
6	3.65	3.21	0.09	0.47
6-7	1.77	0.37	0.52	0.08
7-10	3.8	0.27	1.27	0.18
10-12	1.62	0.19	1.72	0.22
12-15	n/a	n/a	1.82	0.40

Each simulation included 100 replications, 6,570 days each, which was equal to 18 years and 365 days each. A nine-year warm-up period was established. After that time, the model was filled with pupils in each class, and statistics were collected over the next nine years. The main output measure is the average number of pupils with a certain sum of dmft and DMFT. Depending on this sum, each pupil was classified into one of the three Dental Caries States (DCS): good, moderate, or bad (Table 4). Over time, the values of the dmft and DMFT indicators change, which may cause a change in the DCS class. These classes were defined and named by the authors.

Table 3: Prevalence of dental caries in children in Southwestern Poland (Olczak-Kowalczyk et al. 2021).

Years old	dmft/DMFT > 0
6	73.00%
7	75.75%
10	94.00%
12	87.04%
15	89.00%

DCS may be defined as a medical measure that reports whether a given configuration of preventive services and their assumed effectiveness allow one to achieve a health goal for a given group. On the management side, the output measures include the number of dental and nursing hours per year necessary to achieve the desired DCS values. In this way, it is possible to determine how many human resources are needed to prevent dental caries in students in a primary school as part of the planned prevention program.

Table 4: Three states of dental caries state (DCS) depending on the sum of dmft and DMFT in each pupil.

DCS	Dmft+DMFT
Good	0
Moderate	1-3
Bad	4 and more

3.4 Model Verification & Validation

The conceptual model and final results are discussed with dentists. The model was accepted and considered important and useful in supporting the planning of dental caries prevention in Polish primary schools.

Several tests were conducted. As part of the historical validation the equality between simulated and real data for the averages of four indexes (primary teeth, permanent teeth, dmft, and DMFT) was checked in four age groups of pupils. Results were compared only for those age groups for which actual data was available, that is: 6, 7, 10 and 12. Students graduate at age 14, so it was not possible to compare results for students who are 15 years old. The simulation results were consistent with the real data when the average number of primary and permanent teeth was considered (Table 5). When the data for the dmft and DMFT rates were analyzed, noticeable differences were observed between the actual and simulated data. However, the main historical trends were maintained (Figures 2 and 3).

Table 5: Primary and permanent teeth in four age groups; comparison of real data with simulation data of 100 replicates for 100 pupils [avg. - average, sd. - standard deviation, half-width].

Index	Data	6	7	10	12
Primary teeth	Real [avg. ± sd.]	17.64±1.2	14.83±2.85	3.88±3.77	0
	Simulation [avg. ± sd.]	17.64±0.12	14.83±0.13	3.88±0.14	0
	Half-width	0.02	0.02	0.03	0
Permanent teeth	Real [avg. ± sd.]	4.25±2.59	8.89±2.87	19.65±4.03	25.59±2.94
	Simulation [avg. ± sd.]	4.27±0.25	8.97±0.25	19.67±0.26	25.34±0.22
	Half-width	0.05	0.05	0.05	0.04

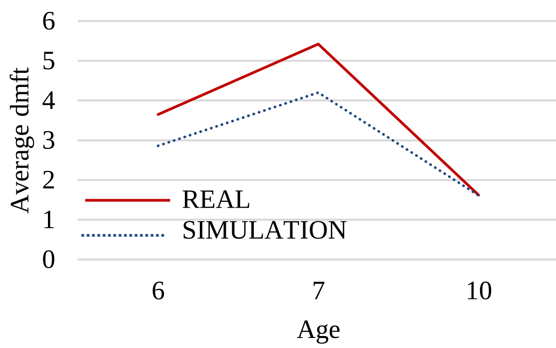

Figure 2: Comparison of trends for real and simulation dmft index; average of 100 replications for 100 pupils.

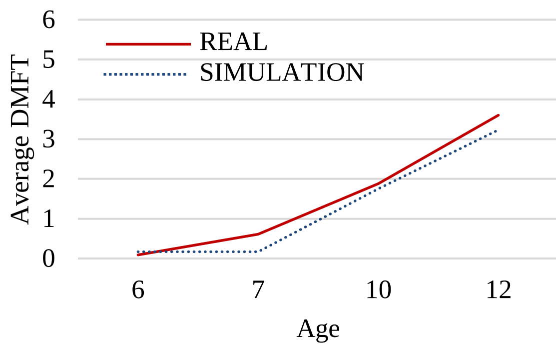

Figure 3: Comparison of trends for real and simulation DMFT index; average of 100 replications for 100 pupils.

Based on the historical validation, the results were considered acceptable. It should be emphasized that the data used to build the model were aggregated and did not allow for a reliable reproduction of real changes. In addition, the model is not intended to predict health status, but was developed to support decisions related to the planning of preventive care.

Thus, the accuracy of the model was verified. One of the tests was to check whether the entities that occurred in the system should leave the system when the simulation ended. This test was completed positively and expectations were achieved. The verification and validation results are sufficient to conclude that the model is well-suited for the purposes of this study, given the aggregate available real-world data.

4 SIMULATION RESULTS

4.1 Base Case Scenario

A series of scenarios was developed to evaluate, through computer simulation, the possibility of reducing dental caries in children in Southern Poland using different configurations of dental caries prevention services. The real data on dental indices were input into the DES model, and the simulation was performed for nine years of education, in which the sample calendar corresponding to the 2021/2022 school year was applied. In the base case scenario, the influence of various preventive services was not considered because, in reality, there were no such services. As in the simulation results, the average DMFT (Table 6) and the average number of pupils in particular DCS classes (Table 7) are presented. The results are presented for the same group of pupils throughout primary school education.

4.2 Overview of What-If Simulation

The effectiveness of preventive services is difficult to define clearly; therefore, multiple scenarios must be considered when planning the coverage of such services. We developed and tested three scenarios. The experiments were designed to demonstrate that a discrete event model can be used to study different scenarios of caries prevention services in schoolchildren.

In the literature, studies are available on the effectiveness of various preventive services; however, to the best of our knowledge, there are no reports on the effectiveness of dental fluoridation along with sealing and education among schoolchildren. Therefore, based on reliable reports from the literature that were as close as possible to those in this study, three baseline values were used to determine the effectiveness of the preventive measures taken in the model. Sealing reduces the risk of caries in permanent teeth by 79% (Wright et al. 2016). Fluoridation reduces the risk of caries by 28% and 20% for permanent and primary teeth, respectively (Marinho et al. 2015). There have also been reports of the positive effects of education, but its effectiveness in reducing the risk of caries has not been clearly and reliably demonstrated (Stein et al. 2018). Based on these values, the effectiveness of caries prevention services was developed by a dental specialist and implemented in the simulation scenarios (Table 8).

As part of the medical preventive services, fluoridation, seals of the first permanent molars, and dental check-ups were included. Educational talks in the groups were considered to be preventive hygienic services. During the dental visits, the teeth to be sealed were identified and sealed by the dentist. In addition, their purpose was to provide the legal guardians of children with information about treatment needs, but this was not addressed in this research. Each scenario assumed a different configuration of preventive services (Table 9), which resulted in a different number of specialist hours needed to meet the planned services.

Table 6: DMFT index at the beginning and end of school. Parameters for the same 100 pupils at the ages of 6 and 14 for 100 replications.

Parameter	Years old	
	6	14
Average	0.17	4.39
Standard deviation	0.03	0.17
Half-width	0.01	0.03

Table 7: DCS classes at the beginning and end of school. Averages for the same 100 pupils at the ages of 6 and 14 for 100 replications.

DCS class	Years old	
	6	14
Good	34.06	11.21
Moderate	27.00	3.48
Bad	38.94	85.31

Table 8: Effectiveness of preventive services in reducing caries development in primary and permanent teeth under three scenarios, simulation distribution with the assumed base value and range.

Scenario	Teeth	Simulation distribution	Base value (%)	Range (%)
Scenario 1	Primary	Triangular	20	16–21
	Permanent	Triangular	28	22.4–29.4
Scenario 2	Primary	Triangular	20	16–21
	Permanent	Triangular	79	79–85
Scenario 3	Primary	Triangular	26	20–30
	Permanent	Triangular	85	79–90

Table 9: Total number of student visits to professionals providing preventive services, such as fluoridation, dental check-ups, sealing of teeth, and education, per primary school education in each scenario.

Type of preventive services	Scenario 1	Scenario 2	Scenario 3
Fluoridation	54	54	54
Dental check-up	0	18	18
Sealing	0	When it is needed	When it is needed
Education	0	0	27

4.3 Results and Discussion

Each scenario involves a different configuration of preventive services. This implies different effectiveness and different use of human resources. Figure 4 shows the average total number of pupils in one of the three DCS classes in each experiment. Table 10 presents the average number of hours during which preventive services are provided.

Table 10: Average number of hours during which preventive services were provided. Results of 100 replications for the three simulation experiments conducted. Dental hours include dental check-ups and sealants; nurse hours include education and fluoridation.

Scenario	Parameter	Check-ups	Sealings	Fluoridations	Education
Scenario 1	Average	0	0	1889.97	0
	Half-width	0	0	0.77	0
Scenario 2	Average	4199.92	224.91	1890.83	0
	Half-width	1.04	0.22	0.94	0
Scenario 3	Average	4200.32	224.92	1890.16	682.94
	Half-width	1.29	0.19	0.91	0.49

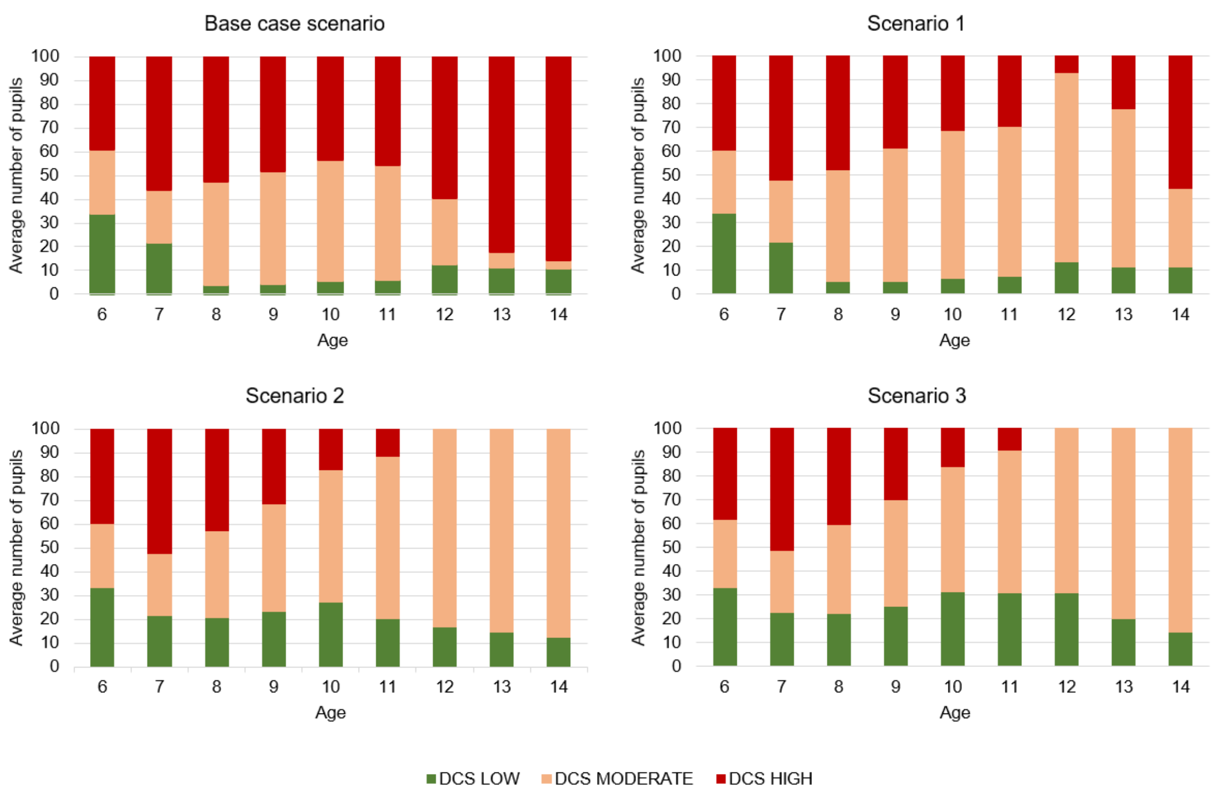

Figure 4: Comparison of the average number of the same group of students with a given DCS class in all experiments conducted; results of 100 replications.

In each of the three scenarios, the average number of students in one of the three DCS conditions was examined. The number varied in each experiment, depending on the preventive services undertaken. The more time and variety of preventive services provided to students, the better their oral health at the end of primary school. Providing check-ups, fluoridation, education, and sealants, as we assumed in Scenario 3, would require a commitment of the number of dental staff hours in size: 491.7 h per year and nurse: 285.9 h per year. Converting this to full time, which in Poland is 40 h per week, in the case of a doctor this is 0.24 and 0.14 full time for a doctor and a nurse, respectively. These hours would have to be allocated for annual preventive care in a sample school of 900 students, assuming that all children are always present at scheduled services. When regional governments have limited access to dentists capable of providing preventive services in schools, they cannot afford to have doctors idle. Assuming that a district has three other schools in addition to this one, doctors could offer prevention in all four schools. On the contrary, nurses were able to educate and provide fluoridation in seven schools. In contrast, dropping education (Scenario 2) did not affect the dentist's workload, but increased the number of schools where nurses could perform fluoridation from 7 to 10.

Analysis of the DSC values showed a noticeable discrepancy between the results from the first experiment and those from the second and third experiments. Fluoridation alone reduces the number of children who graduate with bad DCS from 85 to 56, but 56 children still have four or more teeth with caries. In the second and third experiments, no students left school with a bad DCS; 12 and 15 students left school with a good DCS in the second and third experiments, respectively. Depending on the assumed health goals and the ability to provide human resources to implement the planned service configuration, the model built in this study provides decision support for planning preventive care for elementary schoolchildren.

5 CONCLUSIONS

This study identified the scenario for a caries prevention program among school-aged children, which allows achievement of satisfactory oral health outcomes in students at the end of their primary school education along with human resources at a level that does not exceed the full-time annual employment in Poland. The DES model was developed to examine the oral health of students and the use of human resources in different configurations of preventive services.

The major strength of the proposed approach lies in its ability to address ’what-if’ policy scenarios. By simulating the different scenarios of preventive services provided to pupils and the hours of specialists needed by observing the change in their oral health status during their primary school education, one of the proposed scenarios can be selected and implemented.

The primary limitation of the present study was the limited access to detailed source data. To date, only aggregated data have been obtained. Another limitation is the lack of clear information regarding the effectiveness of preventive services. Numerous studies have been conducted on this topic; however, the problem of dental caries and its prevention are multifaceted. In the present study, we assumed the effectiveness of individual and grouped preventive services and the number of services provided to students based on reports available in the literature and consultation with a dentist. However, it would be valuable to obtain more detailed information on the combination of sealants, fluoridation, and education as a set of services used to prevent dental caries in children as part of primary school prevention programs.

The application of the DES method to simulate the process of providing caries prevention services to primary school students could enable decision makers to plan a set of preventive services that, given a resource limit, will achieve the desired oral health status of children at the end of primary school. Regional health authorities may benefit from such models when allocating healthcare expenditures according to population needs.

The main goal of the next part of the study is to compare the results obtained from different regions and to see if, depending on the region that students live and other characteristics, the same sets of preventive services achieve similar oral health goals in students. In particular, we plan to use discrete event simulations to determine the set of preventive services, their type, and quantity, to determine the need for preventive services in students from different regions and with different demographic and individual characteristics.

ACKNOWLEDGMENTS

This work was supported by a grant from the National Science Centre, Poland, based on decision 2021/41/N/HS4/03282 “Hybrid modelling of the demand for specialist dental care in the field of dental caries prevention in children using computer simulation” (to M.H.) and the Ministry of Education and Science (MEiN), Poland, core funding for statutory R&D activities (to B.M.).

REFERENCES

Brailsford, S. C., P. R. Harper, and M. Pitt. 2009. "An Analysis of the Academic Literature on Simulation and Modelling in Health Care". *Journal of Simulation* 3(3):130–140.

Brunton, P. A., and E. J. Kay. "Prevention. Part 6: Prevention in the Older Dentate Patient". 2003. *British Dental Journal* 195(5):237–241.

Chu, C. H., A. M. Chau, E. C. Lo, and A. Lam. 2012. "Planning and Implementation of Community Oral Gealth Programs for Caries Management in Children". *General Dentistry* 60(3):210–217.

Edelstein, B. L., G. Hirsch, M. Frosh, and J. Kumar. 2015. "Reducing Early Childhood Caries in a Medicaid Population: a Systems Model Analysis". *Journal of the American Dental Association* 146(4):224–232.

Eldabi, T., R. J. Paul, and S. J. E. Taylor. 1999. "Computer Simulation in Healthcare Decision Making". *Computers & Industrial Engineering* 37(1-2):235–238.

Featherstone, J. D. 2000. "The Science and Practice of Caries Prevention". *Journal of the American Dental Association* 131(7): 887–899.

Hajłasz, M., and B. Mielczarek. 2022. "Reflections on Assumptions for a Simulation Model of Dental Caries Prevention Planning in a Primary School". In *Proceedings of the 36th ECMS International Conference on Modelling and Simulation*, edited by I. A. Hameed, A. Hasan, and S. A. A. Alaliyat, 45–50. Nottingham: European Council for Modelling and Simulation.

Hirsch, G. B., B. L. Edelstein, M. Frosh, and T. A. Anselmo. 2012. "A Simulation Model for Designing Effective Interventions in Early Childhood Caries". *Preventing Chronic Disease* 9:E66.

Jaber, M. A. 2011. "Dental Caries Experience, Oral Health Status and Treatment Needs of Dental Patients with Autism". *Journal of Applied Oral Science* 19(3):212–217.

Jenson, L., A. W. Budenz, J.D. Featherstone, F.J. Ramos-Gomez, V.W. Spolsky, and D.A. Young. 2007. "Clinical Protocols for Caries Management by Risk Assessment". *Journal of the California Dental Association* 35(10):714–723.

Johhnson, B., N. Serban, P. M. Griffin, and S. L. Tomar. 2019. "Projecting the Economic Impact of Silver Diamine Fluoride on Caries Treatment Expenditures and Outcomes in Young U.S. Children". *Journal of Public Health Dentistry* 79(3):215–221.

Marinho, V. C., H. V. Worthington, T. Walsh, and L. Y. Chong. 2015. "Fluoride Gels for Preventing Dental Caries in Children and Adolescents". *The Cochrane Database of Systematic Review* 2015(6):CD002280.

Mathur, V. P., and J. K. Dhillon. 2018. "Dental Caries: a Disease which Needs Attention". *Indian Journal of Pediatrics* 85(3):202–206.

Olczak-Kowalczyk, D., A. Mielczarek, U. Kaczmarek, A. Turska-Szybka, E. Rusyan, and K. Adamczyk. 2021. *Monitoring the oral health status of the Polish population 2016-2020: caries disease and periodontal tissue status of the Polish population: summary of the 2016-2019 survey results (in Polish).* Warsaw: Dział Redakcji i Wydawnictw Warszawskiego Uniwersytetu Medycznego.

Scherrer C. R., P. M. Griffin, and J. L. Swann. 2007. "Public Health Sealant Delivery Programs: Optimal Delivery and the Cost of Practice Acts". *Medical Decision Making: an International Journal of the Society for Medical Decision Making* 27(6):762–771.

Polish Parliament. 2019. “Act on Healthcare for Students” (*in Polish*). Polish Law Journal.

Powell J., and N. Mustafee. 2014. “Soft or Approaches in Problem Formulation Stage of a Hybrid M&S Study”. In *Proceedings of the 2014 Winter Simulation Conference*, edited by A. Tolk, S. Y. Diallo, I. O. Ryzhov, L. Yilmaz, S. J. Buckley, and J. A. Miller, 1644–1675. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Selwitz R. H., A. I. Ismail, and N. B. Pitts. "Dental caries". 2007. *Lancet* 369(9555):51–59.

Statistics Poland. 2022. Local Data Bank, Primary Education. https://bdl.stat.gov.pl/BDL/dane/podgrup/temat, accessed 13th April.

Stein C., N. M. L. Santos, J. B. Hilgert, and F. N. Hugo. 2018. "Effectiveness of Oral Health Education on Oral Hygiene and Dental Caries in Schoolchildren: Systematic Review and Meta-analysis". *Community Dentistry and Oral Epidemiology* 46(1):30–37.

Wang N. J., C. Källetstål, P. E. Petersen, and I. B. Arnadottir. 1998. "Caries Preventive Services for Children and Adolescents in Denmark, Iceland, Norway and Sweden: Strategies and Resource Allocation". *Community Dentistry and Oral Epidemiology* 26(4):263–271.

World Health Organization. 2017. *Sugars and Dental Caries*. https://www.who.int/news-room/fact-sheets/detail/sugars-and-dental-caries, accessed 12th January 2022.

Wright J. T., M. P. Tampi, L. Graham, C. Estrich, J. J. Crall, M. Fontana, E. J. Gillette, B. B. Nový, V. Dhar, K. Donly, E. R. Hewlett, R. B. Quinonez, J. Chaffin, M. Crespin, T. Iafolla, M. D. Siegal, and A. Carrasco-Labra. 2016. "Sealants for

Preventing and Arresting Pit-and-Fissure Occlusal Caries in Primary and Permanent Molars: a Systematic Review of Randomized Controlled Trials - a Report of the American Dental Association and the American Academy of Pediatric Dentistry". *Journal of the American Dental Association* 147(8): 631–645.

Zhang X. 2018. "Application of Discrete Event Simulation in Health Care: a Systematic Review". *BMC Health Services Research* 18(1):687.

AUTHOR BIOGRAPHIES

MARIA HAJŁASZ was born in Poland and went to Wrocław University of Science and Technology, where she studied management science and obtained her degree in 2018. She is still associated with Wrocław University of Science and Technology. She works as an Assistant in the Department of Operations Research and Business Intelligence and she is a PhD student in management and quality studies. Her research includes decision support in the management of preventive healthcare using simulation methods. Her e-mail address is: maria.hajlasz@pwr.edu.pl.

BOŻENA MIELCZAREK is currently an Associate Professor in the Department of Operational Research and Business Intelligence, Wrocław University of Science and Technology (WUST), Poland. She received an MSc in management science, a PhD in Economics, and a D.Sc. in Economics from the Wrocław University of Science and Technology. Her research interests include simulation modelling, health service research, decision support, hybrid simulation, and financial risk analysis. She is the head of the MBA executive program at the WUST. Her e-mail address is: bozena.mielczarek@pwr.edu.pl.