Simulation of a School Canteen to Understand Meal Duration Impact on Food Waste

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Abstract - **A system simulation is a one of the approaches to understand business processes or to explain them to other people. It is an excellent decision making solution to provide data-driven conclusions based on system modelling and experiments. This paper proposes simulation results of a school canteen. The aim of the research was to investigate the relation between a food waste amount and meal time duration. The proposed simulation was based on business process analysis, business process modelling, a Monte Carlo method and expert knowledge. The frequency distributions were constructed based on children meal duration observation completed by their mothers. It is a magnificent citizen science solution to involve mothers in the research because they can additionally better understand their children meal preferences and habits. Therefore, a questionnaire for citizens was developed, which can be applied to collect statistical data for model accuracy improvement and extension.**

Keywords - food waste; modelling; school; simulation.

INTRODUCTION

Food waste has increasingly gained attention over the last years both at global and at European level. In the period of time 2011-2016, zero food waste became a more often topic of discussion at all political levels.

In 2011, the European Commission identified food as one of the key sectors where resource efficiency should be improved [1].

In 2015, the G20 stated that "the reduction of food loss and waste is a good objective for G20 collective action", but the United Nations indicated in its agenda for sustainable development that, by 2030, it aimed to "halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" [2-3].

In 2016, the Council of the European Union supported efforts of all actors to reduce food waste, which would contribute to achieving SDG 12.3, which aimed at halving per capita global food waste at the retail and consumer level and reducing food losses along production and supply chains, including post-harvest losses by 2030 [2].

Situations which generate food waste can be very different, but they occur at every stage of the food supply chain from farms to processing and manufacturing to shops, restaurants and at home.

There is an sufficiently small number of researches related to food waste, which were completed in Latvia. Meanwhile, the published data are not precise enough. Previously, the researches about zero food waste in schools are not mentioned too. However, foreign researchers completed many investigations related to food waste amount, their sources and cause factors.

Martins et al. (2020) completed a sophisticated review of factors influencing food waste during lunch of school

children. The main factors identified as positively influencing the reduction of plate waste during lunch in primary schools were as follows: the presence of teachers during mealtimes, the possibility of children leaving the canteen whenever they want and the level of satisfaction with the sensory characteristics of meals [4]. Meantime, sensory characteristics and satisfaction with food is investigated by Ervina et al. (2020) [5].

The topic of our research is the development of a school e-mentor system, which is possible to forecast food waste and provide recommendations to reduce its amount. However, due to the lack of open data, which depicts time-series of food waste amount and considering the restricted access to collect data in schools due to the prevailing Covid-19 situation, we decided to construct a Monte Carlo model to generate synthetic data for neural network pre-training using a transfer-learning strategy and to better understand influencing factors. Additionally, the simulation model can be directly applied as a module in the proposed e-mentor system. The current research proposes our pilot study, which investigates two factors: meal duration and food dislike. However, it is important to identify required statistical data to develop an appropriate questionnaire for crowdsourcing.

MATERIAL AND METHODS

The requested time to eat a dish (T) is generated by the Monte Carlo model. The food waste (w) depends on eaten amount (e), and a part left behind (d), if a child dislikes a dish:

$$w - d = (1.0 - d) - e(t) , \quad (1)$$

where $t \in T$ is the length of lunch.

To simplify the model for simulation, all dishes were summarized in three groups: 1) an easily chewing main dish; 2) a hardly chewing main dish; 3) a soup together with a hardly chewing main course. Food like fruits or deserts, as well as drinks like juice or milk were ignored because they can be eaten/ drunk fast or taken to the classroom.

According to the mothers who have participated in the interview, the part left behind (d) can be less than 20%. Meanwhile, the velocity of eating is different for each type of meal. It is similar and constant in the cases of a soup or an easily chewing main course. In the case of a hardly chewing main course, the velocity of eating is different for the first and the second parts. It is double smaller for the second part simultaneously being constant.

Thus, the eaten part soup or an easily chewing food e_s can be calculated by Eq. 2:

$$e_s(t) = t/T , 0 \leq t \leq (1 - d)T . \quad (2)$$

If the linear velocity decrease is considered for the hardly chewing food e_m (see Fig.1), the time moment of the second part can be calculated using the next system:

$$\begin{cases} \frac{3}{4} v_0 t = 0.5 \\ \frac{v_0}{2}(T - t) = 0.5 \end{cases} \quad (3)$$

$$t = \frac{2}{5}T . (4)$$

Thus, the initial velocity of eating can be calculated by Eq. 5:

$$v_0 = \frac{5}{3T} . \quad (5)$$

At the same time, the eaten part $e_m(t)$ can be calculated by next Eq. 6-8:

$$e_m(t) = \int v(t)dt . \quad (6)$$

$$e(t) = \begin{cases} \int \left(v_0 - \frac{5v_0 t}{4T} \right) dt, & 0 \leq t < \frac{2}{5}T \\ \int \frac{v_0}{2} dt, & \frac{2}{5}T \leq t \leq T - \frac{2d}{v_0} \end{cases} \quad . \quad (7)$$

$$e(t) = \begin{cases} v_0 t - \frac{5v_0}{8T}t^2, & 0 \leq t < \frac{2}{5}T \\ \frac{v_0}{2}t, & \frac{2}{5}T \leq t \leq T - \frac{2d}{v_0} \end{cases} \quad . \quad (8)$$

A soup together with a hardly chewing main course (e_t) must be calculated using Eq. 2 and Eq. 8 simultaneously:

$$e_t(t) = \{ e_s(t_1) + e_m(t_2) \mid t = t_1 + t_2 \}. \quad (9)$$

The probability distributions of meal duration are based on an expert evolution of three voluntary mothers who observed the meal process of their children. The children were not restricted with time. The summary of the evaluation is provided in Table 1.

The observations were based on traditional family dishes. Therefore, dislike probability (p) is unknown – it will be simulated to depict situations when schools monitor or ignore children preferences in the menu. Other, the main variable of experiment, is lunch duration. The variables of experiments are described in Table 2.
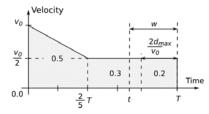

Fig. 1. Simulation scenario of the Monte Carlo model.

Table 1 Parameters Defined by Experts

Meal Type	Parameter	Units	Distribution type	Mean (μ)	Std. dev. (σ)
Soup	Required time (T)	seconds	normal	225	30
	Left behind (d)	%	normal	15%	2.5%
Easily Chewing Main Dish	Required time (T)	seconds	normal	285	30
	Left behind (d)	%	normal	15%	2.5%
Hardly Chewing Main Dish	Required time (T)	seconds	normal	660	120
	Left behind (d)	%	normal	15%	2.5%

Table 2 Variables of Experiment

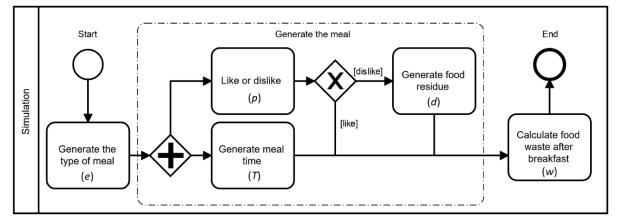| Parameter	Units	Min	Max	Step
Lunch time (t_{max})	minutes	5	20	1
Dislike probability (p)	%	0%	25%	1%

Fig. 2.   Simulation scenario of Monte Carlo model.

RESULTS AND DISCUSSION

The simulation was based on the observations made by three voluntary mothers. Of course, it is not a sufficient number to simulate a realistic situation. However, this is a sufficient amount of data to complete the pilot study. The objectives of this study was to select technologies, to provide the concept of a mathematical model and to obtain some statistical data, which depict relations among parameters to develop a crowdsourcing questionnaire.

The results of simulations are depicted in Fig. 3, which depicts food waste dependence on lunch duration and dislike probability. To simplify the investigation of the results obtained, the tomograms of the minimums and maximums are provided too (see Fig. 4).
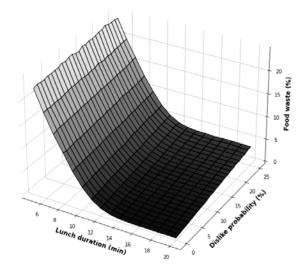

Fig. 3.   Simulation results: food waste dependence on lunch duration and dislike probability.
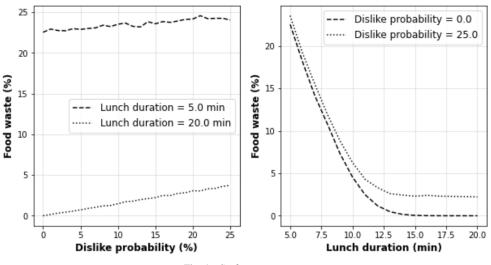
Fig. 4.   Surface tomograms.

It is possible to see that incorrect lunch duration can provide the large amount of food waste, because it has exponential form. According to our pilot data, the minimal duration is 15 minutes, which do not include arrival time. Considering the satisfaction with food, it provides smaller amount, because it has linear dependence. Thus, lunch duration must be set before the school starts to optimize their menu considering children preferences.

Comparing the results with other investigations reveals that Zandian et al. [6] identified the average meal duration 8.8 min for boys and 10.7 min for girls, providing references to similar observations, which is close to expert data applied in the simulation. Meanwhile, Cohen et al. [7] provided another important finding that students ate significantly less of their entrée, milk, and vegetable when they had less than 20 minutes, suggesting that they likely did not have enough time to fully consume their meal. It means that average lunch duration can be increased in some cases. For example, Hamdi et al. mention average lengths 17 and 18 minutes [8].

Speaking about the questionnaire, next data must be collected to improve the model: children age, arrival time, part of a disliked dish left behind, eating duration for easily and hardly chewing food.

CONCLUSIONS

The Monte Carlo model was developed, which can be directly or indirectly applied to forecast food waste depending on meal duration. The obtained results are comparable with the investigations of other researchers.

ACKNOWLEDGEMENT

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