Influence of available resources on the defect elimination

Dalibor Vytlačil[1,*]

[1]Czech Technical University in Prague, Faculty of Civil Engineering, Department of Engineering Informatics, Thákurova 7, 16629 Prague, Czech Republic

Abstract. The paper investigates the influence of resources that we need for maintaining the buildings. The quality and quantity of the maintenance works ensure the level of services that are provided for building users. The solution is based on the system dynamics methodology. The model has been developed where the main input parameters are available resources – components for the maintenance of the building, workers and financial resources. The main output parameter is number of defects and the balance of the financial resources. This parameter includes the costs of the planned maintenance and costs of the repair works. The case study presents the calculation of main parameters. The outputs demonstrate the importance of well-designed budget and adequate hire rate.

1 Introduction

The number of defects is strongly influenced by the maintenance that is realized in the building and is related to the building structure and the HVAC systems.

The capacity of the maintenance depends on the number of workers and their productivity. The maintenance can be considered as planned maintenance and solving ad-hoc problems, usually repairs. The human resources management is one of the most important part of the facility management. It includes the allocation of workers for both kinds of maintenance but also the decision about hiring new workers in the case of the worker shortage.

The materials and components are another resources that we need for the maintenance. The important task is balancing the level of the spare parts stock. In case of the deficiency it can cause the decrease of the service level [1].

All activities are connected to the financial resources. For the maintenance services one year budget is usually proposed. The importance of this resource is evident. It covers all expenses as manpower, materials, components and overhead costs. All these costs are running costs but it is necessary to consider also investment costs for the equipment that is used for the maintenance activities [2].

The paper investigates the dynamic behaviour in the case of restricted resources and it is focused on the financial resources, manpower and the material. As other system model it is simplified with considering the relevant elements.

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* Corresponding author: vytlacil@fsv.cvut.cz

2 Method

The model is developed as the system dynamics model. The method is suitable tool for the description of the dynamic behaviour of the technical, economic and social systems. The main parameters are considered as the stock elements or the flow elements that change the stock values [3-4].

The basic model is described in [5]. For the investigation of the presented problem the model has been changed by adding new elements and by changing input values of the parameters.

3 Model description

The model is depicted in Figure 1. The investigated elements in the model are *Budget* and *Active worker maintenance*, *Active worker repair*, *Available workers* together with the flow element *hire flow* and the convertor element *hire rate*.

The first simulation was performed for the situation when the budget is high enough to cover all expenses and it means the budget does not influence the service operations in the building.

The next simulations were done for different values of year budget planned for the maintenance work.
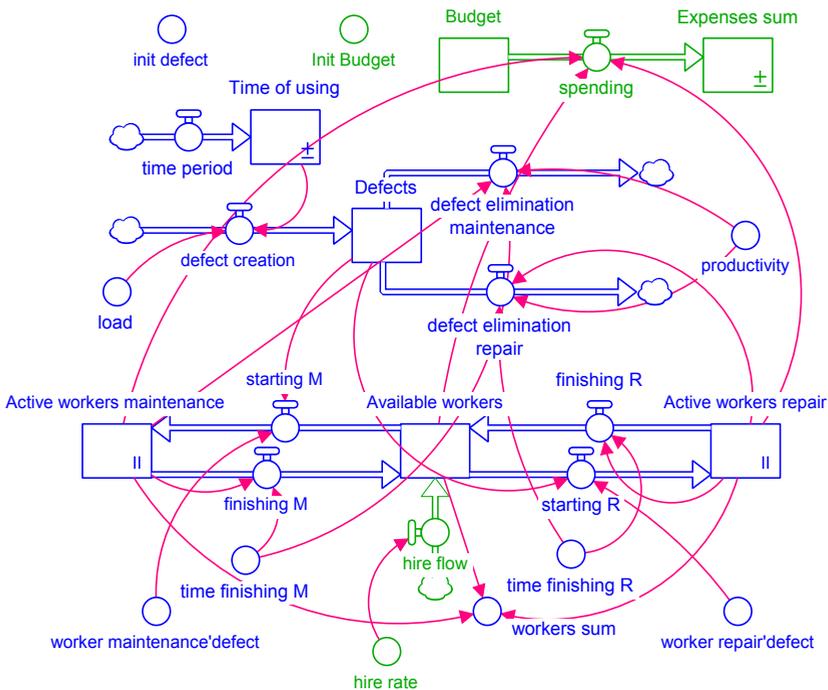
Fig. 1. Dynamic model with the budget element and hire rate element.

The changes of the main system parameters are described by the Equation 1 and Equation 2 for worker parameters and in Equation 3 for defects. Input parameter values are in Table 1. There are initial values that are changed during the simulation. The initial values can substantially influenced the dynamics of the parameter changes.

$$Active\_workers\_maintenance(t) = Active\_workers\_maintenance(t - dt) + (starting\_M - finishing\_M)dt \quad (1)$$

$$Active\_worker\_repair(t) = Active\_workers\_repair(t - dt) + (starting\_R - finishing\_R)dt \quad (2)$$

$$Defects(t) = Defects(t - dt) + (defect\_creation - defect\_elimination\_maintenance - defect\_elimination\_repair)dt \quad (3)$$

Table 1. Input parameters – initial values.

Parameter	Unit	Value
Active worker maintenance	[-]	0
Active worker repair	[-]	0
Available workers	[-]	3
Initial value *Defects*	[-]	0
Budget	[CZK]	13.10^6
Hire rate	[worker.month^{-1}]	0
Time finishing M (maintenance)	[month]	1
Time finishing R (repair)	[month]	0,5

4 Results

The resultant values for the first case are in Figure 2. It is possible to observe the increase of the active workers by a reason of defects increasing and at the same time available workers decreasing.
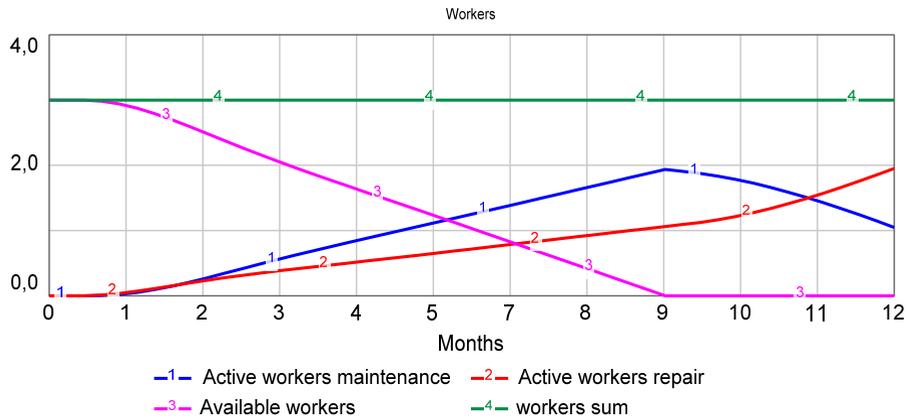

**Fig. 2.** Changes of active and available workers.

With less and less available workers it is evident from Figure 3 that number of defects grows very quickly. This development can be stopped by hiring more workers. It can be ensured by hiring 0,2 worker by every month, it means 2 or later 3 workers by year with adequate increasing the budget by $0,45.10^6$ CZK per year. This solution can be used for stable conditions. Another strategy is to change the parameter *defect creation* that depends on the time and the load. It can be arranged during the design process (e.g. using more reliable materials) and during the construction period (the quality of the construction works).

The material stock changes are depicted in Figure 4. The sustainable supply of material is 9.6 material unit per month and year consumption is 115 units.

The next investigation was focused on the influence of the budget on the number of defects, active workers for planned maintenance and active workers for repairs. These parameters are interconnected because low budget influences the level of maintenance activities and consequently the defect creation. The budget is changed from 4.10^6 CZK.year^{-1} to 14.10^6 CZK.year^{-1} in seven steps. The output values are presented in Figure 5 – 7.
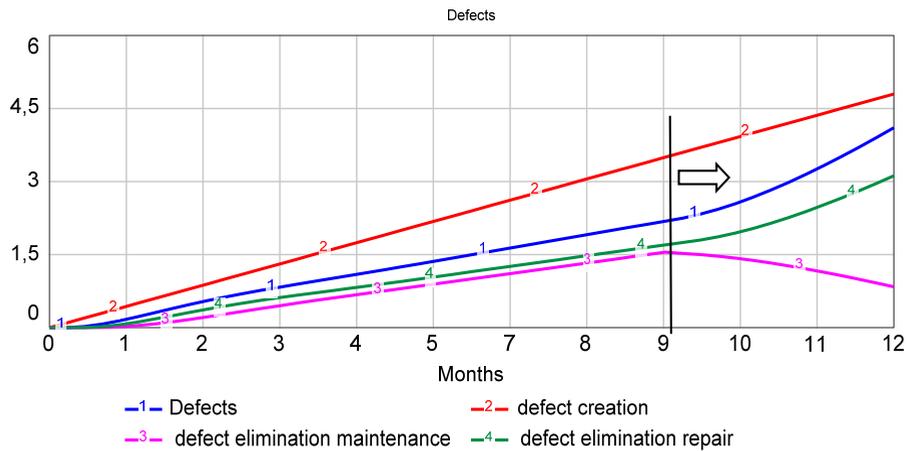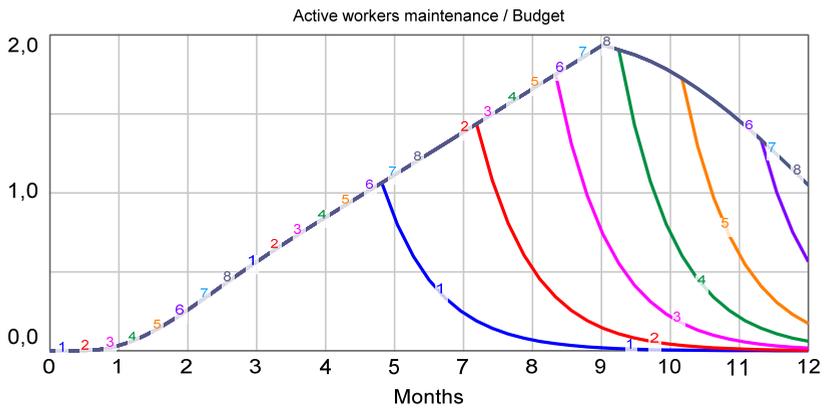

Fig. 3. Defects and defect creation and defect elimination.
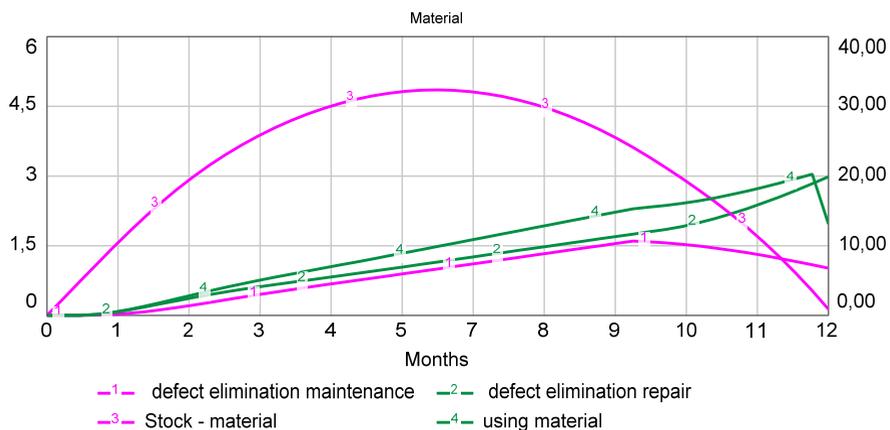
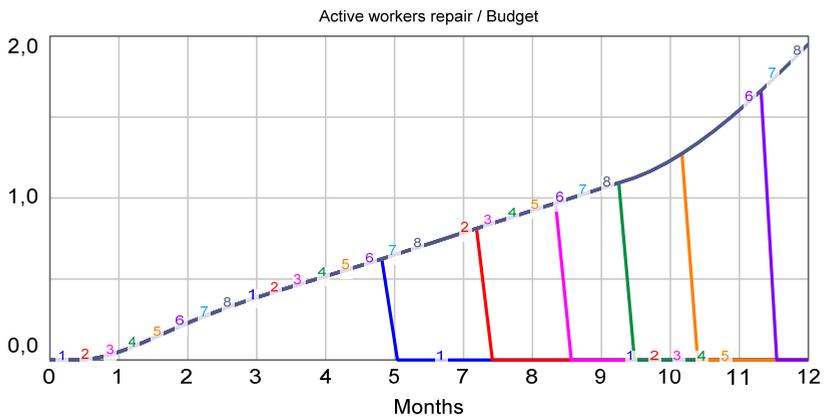**Fig. 4.** Consumption of materials (material parameters – right axis).
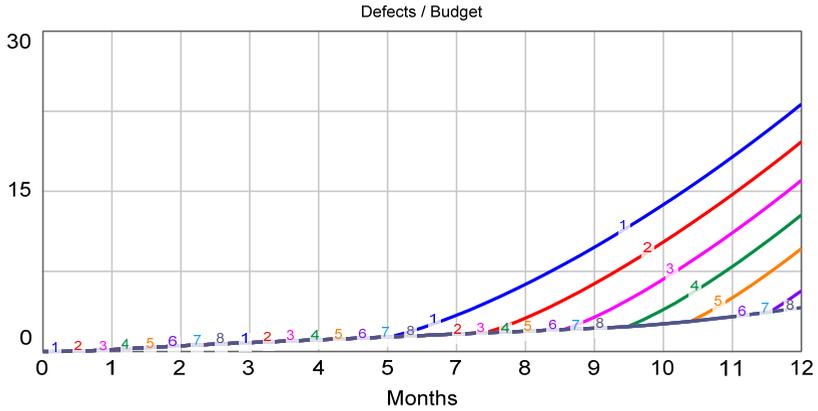
Fig. 5. Defects according to available budget – from 1-4.10^6 CZK.year^{-1} to 8-14.10^6 CZK.year^{-1}.

Fig. 6. *Active worker maintenance* according to available budget – from 1-4.10^6 CZK.year^{-1} to 8-14.10^6 CZK.year^{-1}.

Fig. 7. *Active worker repair* according to available budget – from 1-4.10^6 CZK.year^{-1} to 8-14.10^6 CZK.year^{-1}.

After the budget depletion the number of defects is immediately increased. The final value of defects for the budget level 4.10^6 CZK is five times higher than in the case of the sufficient budget.

The consequences of low budget are evident also for human resources. Without the possibility to cover the personal costs the number of active workers decreased to zero.

4 Conclusions

The developed model allows us to investigate the complex system and to do the decisions concerning the maintenance activities in the buildings. These activities are influenced by available resources as the manpower, materials and the planned budget.

The model does not cover the building refurbishment. The improvement of the building structure and HVAC systems can, after the implementation, substantially change the number of defects. The time of ageing is considered from the end of the refurbishment works.

It is necessary to pay more attention to the design activities. It means to use elements with well described parameters including the maintenance work demand and the implementation conditions. The solution can bring BIM approach where construction elements use this data. The skills in using BIM tools relevant to the work performed by each professional or technical participant is also a necessity [6]. It influences the productivity of the design work but also operations in the buildings.

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