Chapter 6
Cost Assessment of Training Using Constructive Simulation

Martin Hubacek and Vladimir Vrab

Abstract Modeling and simulation represent a common part of most human activities. Development of computer technology causes a massive advancement of computer simulation. Computer simulation offers many new views on the modeling and simulation while allowing penetration of simulation into other disciplines. Simulation has an irreplaceable role in the fields of training and education for centuries. Its application and development are largely associated with its use in the military. There is an analogous situation with constructive simulation, which is used as a tool for training of commanders and staffs of military units. The benefits of simulation for a higher quality of training are beyond doubt. Therefore, constructive simulation gradually penetrates into other spheres such as the training of emergency staff. However, relevant studies about the economic benefits of the use of constructive simulation for training are relatively rare. The presented cost comparison of the exercises is based on the authors' experience gained during the implementation of various types of exercise at the Center of Simulation and Training Technologies Brno with the use of constructive simulation OneSAF.

Keywords CAX (computer assisted exercise) • Training • Constructive simulation • Calculation of coasts

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6.1 Introduction

Simulation of human activity is a phenomenon which is exploited for centuries. Its use is very varied and has many forms. Children perform unconsciously simulation during their games when they imitate adults and their activities. Various games were used to simulate the military conflict since the ancient times. Since the industrial revolution machine models were used to determine the behaviour of the real machine (Bennis 1966; Hudson 2014). Development of computer technology has caused a great progress in the field of modelling and simulation in the 20th century. This was also evident in the field of training and education of people. This part of the simulation has always been primarily developed especially in the military, whose approaches and technologies were later generally applied in other domains of human activities (Hofmann et al. 2013).

Generally three basic types of simulation are used in training. These are live, virtual and constructive simulations. Live simulation is a classic training in the field, which is carried out from the time when the first military units started to be organized. It was perfected through the use of a variety of sophisticated systems for simulation of effects of lethal and non-lethal weapons. Its main purpose is to conduct training with real equipment like during a real deployment. In contrast, virtual simulations use models of equipment (vehicles, weapon systems, …) for training people and thus saving real equipment and the cost of operating machines. Training of individuals, crews and small units is the primary objective of these kinds of simulation. The last type of simulation (constructive) is designed for training commanders and staffs of larger units. This kind of simulation was fully developed after the emergence of computer technology. It is therefore the youngest simulation type, although the staff exercises on maps and various war games can be considered as its forerunner.

Development of virtual reality, more accurate mapping of terrain and new information technologies enabled significant development of virtual simulation, however, constructive simulation still has its justification and it is irreplaceable in training of staffs. This article will be devoted to constructive simulation and evaluation of cost training of staffs in different types of operations. The results are based on the authors' experience gained from more than fifteen years of action on the Center of Simulation and Training Technologies (CSTT) in Brno, which is a training facility of the Army of the Czech Republic.

6.2 The Used Simulation Tools and Their Utilization

The CSTT uses constructive simulation system based on semi-automatic behavior SAF (Semi-Automated Forces) for training of commanders and staffs since its inception in 1999. ModSAF (Modular Semi-Automated Forces) was the first one and it was gradually replaced by a system OTB (OneSAF Testbed Baseline).

Currently OTB is used along with the new system OneSAF (One Semi-Automated Forces). This system is used in other countries especially in the United States, Australia, Slovakia and others (Grega and Bucka 2013; Lui and Watson 2002; Macedonia 2002; Prochazka et al. 2002; Wittman and Courtemanche 2002). The main principles of simulation and simulation environment are preserved in all development versions. It was always system with minimal aggregation and semi-automatic behaviour, which can be influenced by the system operator according to the order of commander of simulated unit. The staff participating in the training is physically separated from the simulation and its members can communicate with subordinate units using only radio, telephone and data communications. If necessary, it is possible to transmit the 3D images of simulated situation to the command post. Simulation system is also connected to the command and control system. This connection allows to transmit some information from the simulation to command and control system. The information is similar to those in the real command and management systems. These include mainly data about the position and status of vehicles and other weapon systems.

As stated above, CSTT had been providing training for several years and it extended the range of operations from the primary capability to conduct primarily combat operations to training units for missions abroad, training in the deployment of army units in favour of the Integrated Rescue System (IRS) and the preparation of specific units such as military engineers, military police etc.

Expanding the capabilities of the simulated activities brought greater possibility of using the simulation center. Combat units are not currently the only exercisers on CSTT. Units designed for use in foreign operations, engineer and rescue units, military police, air defense units, units of the integrated rescue system (especially firefighters and police) use constructive simulation for their training today. Table 6.1 shows the relationship between combat exercises and non-combat exercises over the past 10 years. Qualitative benefits in the training of commanders and staffs of units are unambiguous and indisputable. It is mainly due to continuous capacity utilization of the center. The question then arises, whether such center

Table 6.1 The number of exercises in the individual categories over the past 10 years

	Battle operation	Rescue operation	Stabilization operation	Other
2006	9	1	1	0
2007	7	3	1	0
2008	6	1	1	2
2009	8	2	3	2
2010	5	1	3	3
2011	7	3	3	3
2012	4	2	3	0
2013	8	4	4	0
2014	6	9	4	0
2015	2	8	2	5

provides any economic benefits in comparison with field training (Maturo and Hoskova-Mayerova 2017).

In general, the widespread opinion prevails that training using simulators is significantly cheaper than field training using real machinery and equipment. Literature and other available sources concerned with training and simulations do not provide enough evidence for this claim or instructions for comparing the costs of comparable field training and training using solely simulation technologies. One can readily agree with many conclusions about the benefits of training with simulation technologies (Smith 2009; Rybar et al. 2000; Vrab 1998), which mainly apply to:

- possibility of repeating the same training session;
- training staff in safe conditions;
- saving costs for fuel and ammunition;
- causing no damage to the environment and countryside;
- reduction of the impact on the environment (no disturbance of everyday life of the population);
- identifying weaknesses in the decision-making process.

Even though these benefits are undeniable, and many of them would also offset any potential increased costs of training using simulation technologies because the possible losses of life and damage to environment are hard to quantify.

The following chapters outline the way compared to the cost of training at the CSTT compared to the cost of making the same field exercises using real techniques.

6.3 Evaluation Model of the Training Efficiency

The basis of the model for calculating the efficiency (or rather costs) of an exercise stems from the premise that in an analytic formula for calculating the costs, identical variables are accepted that characterize a given phenomenon, process and behaviour as a process of constructive, virtual, and live simulations (training in a real environment). The relationship for calculating the costs associated with exercise N_{cv} can be expressed by the following equation:

$$N_{cv} = (N_a + N_b + N_t + N_p + N_m + N_s + N_h + N_u + N_n) \cdot k \tag{6.1}$$

where

- N_a refers to the costs of machinery employment during the exercise [CZK],
- N_b refers to the rental costs of the area for the exercise [CZK],
- *Nt* refers to the costs of technical equipment [CZK]
- N_p refers to the costs of support of the exercise [CZK],
- N_m refers to the costs of consumed ammunition [CZK],

- N_s refers to the costs of boarding of the participants of the exercise [CZK],
- N_h refers to the costs of accommodation of the participants of the exercise [CZK],
- N_u refers to the costs related to maintenance of the equipment, depreciation [CZK],
- N_n refers to the costs that have not been specified yet [CZK],
- k is a tolerance coefficient.

The variable N_a represents the cost of using all types of machinery during the exercise (passenger cars, transport vehicles, trucks, special vehicles, aircrafts, reconnaissance aircraft etc.). Its value can be expressed as:

$$N_a = \sum_{j=1}^{n} a_j \cdot l_j \cdot c_j \tag{6.2}$$

where

- a_j refers to the number of pieces of j-th piece of machinery employed in the exercise,
- l_j refers to the average distance covered by j-th piece of machinery during the exercise in [km],
- c_j refers to the costs of j-th piece of machinery spending on 1 km ride [CZK/km].

The actual amount of mileage in real training can be easily determined with the odometer on used vehicles. In the case of constructive simulation it is only possible in systems with a low degree of aggregation. OTB and its successor OneSAF have a small degree of aggregation. Used tools of AAR (After Action Review) allow to obtain the actual mileage for each simulated vehicle.

Live simulation (real exercise in the field—LIVEX) can take place in areas whose use is a subject to payment for the rental. Quantifying its value is based on prices per m^2 of j-th area (c_j) multiplied by the overall use of the j-th area (P_j) or the total invoiced cost for rental may be put into Eq. 6.1.

Calculation of N_b can be performed as follows:

$$N_b = \sum_{j=1}^{n} P_j \cdot c_j \tag{6.3}$$

where

- P_j refers to the area of j-th sector used during the exercise [m^2],
- c_j refers to the costs of 1 m^2 of j-th sector [CZK/m^2].

In the case of training using virtual or constructive simulation, the cost for renting space equals zero. Exercise may in fact take place in any area. The spatial location of the exercise is possible in any territory which is mapped in a terrain database (TDB) or where the data for building the TDB exist. The cost of TDB is not insignificant, ranging in the hundreds of thousands of crowns, depending on the area and its details. The costs can be potentially increased by the cost of collecting digital geographic data required for the creation of TDB. Because of possible multiple repetitive use of a given TDB, the potential increased costs are considerably reduced with each conducted exercise; unlike with the exercise in real terrain, where it is necessary that new resources are devoted to every other exercise again. Conducting exercises on simulators also allows training in areas that are not available for traditional training for various reasons (territory of another state, different climate area, considerable distance, region with ongoing combat operations, national park or otherwise valuable territory etc.). TDBs of these areas can be created from various data sources (national, allied, international) (Hubacek 2012) or it is feasible to use non-contact methods of data collection for creating of geographic data (Robinson 1995; Kovarik 2011) which ought to be supplemented by information obtained through GEOINT, IMINT methods and geographic analysis.

Calculation of the remaining coefficients is defined in a similar way. A more detailed description can be found for example in Hubacek and Vrab (2012a, b). The proposed procedure was applied to selected exercises, which took place at the CSTT in the recent years. Three representative exercises were selected as representative of the main types of training.

6.4 Selected Exercises and Calculation of Their Costs

Three typical exercises were selected for comparison of the costs of field training and simulator training. These exercises have been regularly practiced by the Czech Army units on the CSTT for more than 5 years. The topics of these exercises are:

- battalion task force in attack
- deployment of military troops on disposal of consequences of natural disasters
- task force in stabilization operation.

Selected exercises were evaluated according to the methodology described above. The calculation was based on parameters that could be quantified. During the training with constructive simulation only some of the expense issues arise. They are mainly:

- service for data processing (partial edits in data files)
- operators of the simulator
- consumption of electricity by the simulator
- accommodation and catering for the participants of the training.

Data extracted from the simulation were used to quantify the cost of the same exercise carried out by in the field. When using the constructive simulation, it is possible to use the data used for presenting entities (models) in the simulator. These data are stated in the Protocol Data Units (PDU) (Pavlu and Vrab 2007). Currently,

Table 6.2 Selected input data entering the calculation of the exercise price

	Battle operation	Rescue operation	Stabilization operation
Number of trainees	55	42	40
Service personnel	30	35	30
Simulation stations	42	49	36
Other used equipment	56	29	62
Number of simulated people	1511	975	527
Number of simulated vehicle	375	183	94
Total mileage covered terrain	10951	2405	862
Total mileage on the road	4661	7283	5429

it is not possible to calculate and quantify all the items according to the methodology described above. For this reason, only the familiar costs and the costs of each item that can be computed from available information are stated. The basic parameters that were used primarily are the following (Table 6.2):

- number of simulated people
- number of simulated vehicles
- mileage
- quantity of consumed ammunition and other material

Values in the table represent the total amount. Vehicles, ammunition and other items were categorized in the calculation by:

- the type of chassis
- the movement in the terrain and on roads
- the type of ammunition and other consumed material

Categorical data and publicly known information on prices were used to calculate the costs of field exercises (Hubacek and Vrab 2012a). Ammunition is an exception, and its cost is based on military tariffs. Some costs may change over time. However, this change is not usually significant and it does not affect the overall relation between exercise in the field and exercises on the simulator. The individual items and the total cost of execution of exercises on the simulator and in the field are summarized in Table 6.3.

The proposed solution procedure is based on publicly known prices in the Czech Republic. The final rating may be different in other countries, or using a different simulation system, or use of other vehicles, weapons and equipment. Some expenses in the calculation of live training is not possible to quantify reliably, therefore it is not included in the calculation. Likewise, the cost of the center construction is not included in the cost of the simulator exercises, while operating costs are included in the price of training. Similarly, the cost of procurement of

Table 6.3 The result of comparing costs between the different kinds of exercises in variations CAX and LIVEX. Prices are in CZK

	Battle operation		Rescue operation		Stabilization operation	
	CAX	LIVEX	CAX	LIVEX	CAX	LIVEX
N_{a1} (vehicle)	5 650	595 000	7 480	215 000	7 480	111 000
N_{a2} (plane)	0	1 600 000	0	1 800 000	0	600 000
N_b	0	0	0	NA	0	0
N_t	1 580	10 560	1 560	4 500	1 460	8980
N_p	320 000	0	150 000	750 000	150 000	300 000
N_m	0	7 830 000	0	0	0	150 000
N_s	42 620	793 270	32 550	377 000	31 000	222 040
N_h	44 000	0	33 600	NA	32 000	105 400
N_u	NA	NA	NA	NA	NA	NA
N_n	NA	NA	NA	500 000	NA	100 000
k	1	1	1	1	1	1
N_{cv}	**413 850**	**10 828 830**	**224 540**	**3 646 500**	**221 940**	**1 597 420**

Note NA—not available in this time

equipment and its amortization are not included in case of a live training. Again, the costs for the exercises are only counted.

6.5 Conclusion

Simulation technologies are increasingly being applied in the area of staff training. Areas of their use focuses not only on the military, but also on other security forces, rescue units and crisis staffs. Their use is advantageous for many reasons, such as the possibility of a repetition of situations, training in geographically varying environment, simulations of all sorts of meteorological phenomena, preventing damage to nature, reducing the impact on the population, and so on. Despite this fact the economic contribution of simulation technologies is debated quite often due to the relatively high costs of acquisition of simulation technique.

CSTT has been existing in the Czech Army for more than 15 years. This unique center was primarily designed only for training military units. Throughout the years, the center has been adapted for conducting of training in non-combat operations and in rescue operations. Free capacities of the center are used by units of the integrated rescue system. The implementation of diverse training can determine the advantages of training in different types of operations. Three typical examples were chosen from more than two hundred realized exercise. Costs for selected exercises have been calculated according to the proposed methodology for both variants of exercise CAX and LIVEX. These cost calculations show a clear economic advantageousness of exercise on a simulator compared to the same exercises in the field. Although all costs are not included in the calculation, calculations show a much higher costs of exercises in the field.

The most economically advantageous is the use of constructive simulation for training of staff in command and control of combat operations. It is mainly due to significantly greater deployment of personnel and equipment in this type of training. Ammunition is another important issue which generates important savings. On the other hand, the number of trained persons is much higher in case of LIVEX than during CAX. Even though, calculations have shown greater profitability of combat units training, simulator training in emergency and non-combat operations is still about ten times cheaper than the same exercise carried in the field. It is necessary to point out the fact that a number of exercise topics can not be carried in the field without restrictions of everyday life. The second advantage is possibility of training of crisis staffs that were never in a control of any operation. Training using constructive simulation can prepare crisis staffs to the real situation, although the most important benefit is the fact that members of crisis staffs can practice in command, control and communication during crisis situations.

The calculations clearly demonstrated the benefits of using constructive simulation for training of staffs. Generally, it can be declared that the economic advantage of using this technology grows with the size of the simulated situation. Costs could be reduced also by the use of model scenarios or parallel training of staff of small units.

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