THE 9TH INTERNATIONAL DEFENCE AND HOMELAND SECURITY SIMULATION WORKSHOP

SEPTEMBER 18 – 20, 2019
LISBON, PORTUGAL

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Co-Chairs' Message

On behalf of the Organization Committee it is our pleasure to welcome you to Lisbon for the 9th International Defense and Homeland Security Simulation Workshop.

Since 2010, the International Defense and Homeland Security Simulation Workshop bring experts together for the purpose of presenting and discussing all type of innovation related to the use of Modeling & Simulation in Defense and Homeland Security applications. Year by year, the workshop has provided meaningful insights on new concepts, methods, techniques and tools for advancing in the modeling & simulation sector.

This year as well, The 9th International Defense and Homeland Security Simulation Workshop lives up to the expectations with an impressive scientific program devoted to foster discussions and hopes to inspire participants from a wide array of themes and to initiate collaborations within and across disciplines for the advancement of the field. Just to give a little taste of what the scientific sessions will offer, main contributions pertain to: 3D modeling, sensors and CBRN applications, target assessment software, deep learning, disaster management, unmanned vehicles and many others

We thank the local staff, participants, session chairs, keynote speakers for helping us to build this very exciting conference program. The Local Organizing and Scientific Committees have made their effort to ensure a scientifically rewarding participation and a pleasant experience in the city of Lisbon rich of art, culture and natural beauty.

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The DHSS 2019 International Program Committee (IPC) has selected the papers for the Conference among many submissions; therefore, based on this effort, a very successful event is expected. The DHSS 2019 IPC would like to thank all the authors as well as the reviewers for their invaluable work.
A special thank goes to all the organizations, institutions and societies that have supported and technically sponsored the event.

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DEEP LEARNING OF VIRTUAL-BASED AERIAL IMAGES: INCREASING THE FIDELITY OF SERIOUS GAMES FOR LIVE TRAINING

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ABSTRACT
The aim of rapidly reconstructing high-fidelity, Synthetic Natural Environments (SNEs) may benefit from a deep learning algorithm: this paper explores how deep learning on virtual, or synthetic, terrain assets of aerial imagery can support the process of quickly and effectively recreating lifelike SNEs for military training, including serious games. Namely, a deep learning algorithm was trained on small hills, or berms, from a SNE, derived from real-world geospatial data. In turn, the deep learning algorithm's level of classification was tested. Then, assets learned (i.e., classified) from the deep learning were transferred to a game engine for reconstruction. Ultimately, results suggest that deep learning will support automated population of high-fidelity SNEs. Additionally, we identify constraints and possible solutions when utilising the commercial game engine of Unity for dynamic terrain generation.

Keywords: synthetic natural environment, live military training, deep learning, simulation fidelity

1. INTRODUCTION

For positive training transfer to occur in a military simulation, the highest possible representation of the natural terrain must be achieved. To exemplify the train-as-we-fight mantra, any scenario represented by game engines needs a high, consistent correlation with the Real World (RW). The effective-and-efficient creation of terrain that meets accuracy requirements for live (such as augmented) military training environments continues to be a significant challenge. Thus, the purpose of this paper is to aid in the rapid reconstruction of Synthetic Natural Environments (SNEs) for training, by simultaneously maintaining both effectiveness (i.e., high fidelity) of the final environment and efficiency (i.e., a low amount of resources) within the reconstruction process. To reach this purpose, the first-tier goal of the paper is multifold: to test the classification accuracy of a deep learning algorithm trained on a SNE, and test the subsequent reconstruction of a SNE based off the classification from the deep learning algorithm. A second-tier goal is to identify constraints in a game engine's terrain generation process, as lessons learned for future research.

1.1. Related Work

Representing RW or geo-specific training regions to a very high degree of RW correlation, while maintaining cost-effectiveness, has been elusive. In one method, scenario environments can be painstakingly built by artists—reducing efficiency and introducing a potential human-error confound to effectiveness. Some alternate solutions have been proposed: one example is the automatic generation of terrain from aerial photogrammetry (Spicer, McAlinden, and Conover 2016). With the advent of low-cost and highly-reliable drone platforms, obtaining dense point-cloud data from either photogrammetric or LiDAR sources has become commonplace. However, processing the dense point cloud into usable and efficient polygonal, game-engine-based geospecific regions of sufficient geographic size to perform on-going mission training remains a challenge. One issue is the high-resolution automatic classification of different features (e.g., capturing the distinction between human-made structures and natural terrain). We distinguish this high-resolution classification from the traditional coarse-grain approach of Digital Terrain Model (DTM) and Digital Surface Model (DSM) methods commonly provided by Commercial-Off-The-Shelf (COTS) software tools. Furthermore, injection of numerous raw or coarse point-cloud-derived polygonal models into the game-engine-based rendering system is both inefficient and distracting for the trainee.
The U.S. Army's One World Terrain (OWT) program is a large program attempting to solve these terrain-related issues. The goal of OWT is to provide foundational, attributed 3D data to runtime publishers (i.e. consumers) that is well-formed and consumable at the Point-Of-Need (PON). OWT will contain polygonal mesh OBJ data and a traditional-gridded CDB standard (e.g. elevation grids, imagery, and vectors). OWT data should be viewable and editable with no proprietary tools required. OWT will leverage Open Geospatial Consortium (OGC) CDB to add rigour, structure, attribution and determinism to OBJ files. Nevertheless, machine learning (via a deep neural network) to classify and reconstruct objects from aerial imagery point clouds has been introduced (Zhang, Li, Li & Liu, 2018). Although the latter avenue of work supplies a classification process, it is limited by training

a deep learning algorithm through non-virtual data, which is a problematic method from the vantage of efficiency.

In the advancement of machine learning, previous research suggests the value (in terms of efficiency and effectiveness) of using virtual, or synthetic, imagery datasets to train object classification of RW imagery: a deep learning algorithm was successfully tested for classification after training on a virtual military helmet (Reed, Thomas, Eifert, Reynolds, Hurter, and Tucker 2018). Although virtual assets have been used to help pre-train for aerial images (Kemker, Salvaggio, and Kanan 2018), or enhance the training process (Chen, Jiang, Li, Jia, and Ghamisi 2016), it is unclear how virtual assets would fair as an exclusive training set for aerial images. Ultimately, the present paper investigates how the artificial-intelligence technique of deep learning can be leveraged to alleviate the burden of having to populate repetitive, but critical, terrain features in a SNE. We also identify and explore shortcomings in the Unity game engine as used to render SNEs.

1.2. Solution Space

The proposed solution for SNE reconstruction is to leverage deep learning to help classify features of an environment; in turn, the classified features can then be utilised to populate a SNE with virtual models and textures rapidly. The focus of this paper's initial test is the classification of berms or small hills (see Figure 1) found in a SNE. For streamlining, the solution is directed at training the deep learning algorithm using virtual, rather than RW, imagery data.

Figure 1: Example of a Berm in a Synthetic Natural Environment (SNE; Image Contrast Increased for Presentation)

One can train a deep learning algorithm to classify geo-specific features from aerial imagery. Once features are learned, one may inject matched features with a high degree of accuracy into the SNE. Given how large defence organisations generally have a preexisting set of high-quality terrain models, which are used to populate geotypical and geospecific SNEs, deep learning serves as a bridge to support automatic modelisation of simulated military environments. Specifically, the U.S. Army has a large resource of assets: with a large set of Synthetic Environment (SE)-Core 3D models library called the common models, the Army can access Games for Training assets (e.g., the Virtual Battlespace game engine or the Army Model Repository; PEO STRI n.d.; Baker 2018). The availability of thousands of 3D models is beneficial for training deep learning algorithms, since these 3D models are existing assets usable for AI training material. This process differs from performing very expensive data collection of RW imagery.

Another linchpin of the solution is the capabilities of game engines. Commercial game engines, such as Unity, offer advanced features for rendering high-quality, natural-looking environments. Thus, game engines provide an apt tool to maintain ecological validity for various military tasks, due to the possibility of high fidelity afforded. However, a restriction arises with game engines: although some engines support the import of dense point-cloud data directly for small regions, the same process does not lend itself to efficient rendering over larger areas. Additionally, native dense point-clouds will inherently contain surface inaccuracies from the source sensor that causes the data to be unusable for traditional simulation. These game engine limitations underscore the need for a more efficient process for large-scale SNE development.

The foreseen reconstruction solution would ideally be routine for an Unmanned Aerial System (UAS), or drone. Once a deep learning system is trained, a UAS could collect data in the form of photos or LiDAR data, represented by a 3D point cloud. Based on the models derived from the point cloud, features would be identified, classified, and then mapped to a terrain object. Once an area is appropriately classified by the deep learning algorithm, it can be seamlessly imported into a game engine, such as Unity.

2. METHODOLOGY

Before detailing the experimental procedure, the second-tier goal of this paper will be covered: the constraints confronted (and solutions found) when attempting to use Unity for dynamic terrain generation.

2.1. Challenges in Unity

Virtual environment developers have a decision to make when deciding on how to implement terrain: in Unity, one option would be to use the built-in terrain editor, whereas another option would be to import a polygonal mesh from another tool. In Unity's 2018.3.8.f1 release (Tchou 2018), updated terrain implementation supports seamless operations between multiple co-located terrain tiles. The native Unity terrain implementation is beneficial, as it allows designers to quickly add content to terrain by applying terrain brushes that paint geotypical content on top of terrain tiles. Another benefit of Unity's native terrain is the relative efficiency of how repeated objects are rendered at runtime. Native implementations of objects, such as trees that are directly handled en masse (in contrast to individually-placed game objects) leads to superior handling in the draw cycle and better overall performance.

An internal preliminary experiment tested the implementation of native Unity terrain trees (i.e., terrain objects) versus individual trees placed as game objects. An individual, traditional 3D tree model was created with three levels of detail. Using the Unity terrain tool, 13,000 trees were painted over a single terrain tile. We then repeated the test but used game objects instead of a traditional 3D model, and placed them at the exact location of each tree in the first test. Locations of the trees were determined by the treeInstances method of the TerrainData Unity object. The Frames-Per-Second (FPS), or framerate, measurements were provided by the FRAPS program. A PC with a dual video card was used to perform this test, with consistent specifications (see Table 1).

Table 1: Testbed Specifications

CPU	Intel Core i7-5960X
Memory	32GB
OS	Windows 10 Enterprise
GPU	2x NVidia GeForce GTX 980 Ti

Ultimately, the native terrain condition used less memory and rendered more efficiently than the game object approach (see Table 2).

Table 2: Terrain Objects Vs. Game Objects, Tree Models

Object Type	Memory	FPS	CPU
Native Terrain	15%	36	6.6%
Game Object	16%	33	12.7%

As the results show, using the Unity terrain system to manage the tree models is more efficient, with respect to computer resources, and provides superior rendering performance.

Despite the Unity game engine's beneficial aspects within the terrain editor, various challenges inherent in using the native Unity terrain processes were found. These issues altered the final methodology used, and are discussed here as part of the methodological rationale. Ultimately, these choices may inform future research when considering the value of Unity's impact on serious military games.

Originally, a detail-mesh placement-map system was tested, where pixel data (in the form of RGB values) corresponded to different mesh objects. When placing terrain objects, manually setting the rotation of objects was unsupported. The system lacked the option for correcting the direction objects faced, on a per-object basis. However, the objects could be instructed to face the camera consistently (i.e., an option for billboarding existed). Further, the scaling of mesh objects was limited; this is a fundamental difference between injecting native terrain features and injecting representative game objects into an environment: typically, a game object can be used repeatedly with various scales. In contrast, Unity's native terrain-feature scales are set uniformly, breeding inefficiency: to account for scale variations of terrain, different-size versions of the same object would be needed, in turn requiring multiple maps. Another crucial control issue with the aforementioned map process was the non-deterministic placement of models: when an identical map was reloaded, the locations of models were not necessarily identical to the previous load. A similar non-deterministic issue involved the terrain brush settings for painting pixels on the map, due to the inability to consistently equate one model to one pixel. If the brush size was too large, multiple objects were placed; but if the size was too small, there was a chance no objects would be placed. Further errors may also be caused here if a user changed the settings on detail resolution.

Another issue within the map used was the lack of collision between objects. The lack of collisions is problematic since it reduces the fidelity of the environment: although the visuals may look real, they would not function realistically. For example, an avatar could walk through a berm or shoot a bullet through a berm; this defeats the purpose of the current project's goal (at least for some types of ground-based training). The detail-map size must also be consistent with the terrain size: if the sizes did not match, the terrain system would attempt to rescale the map, which skewed the placement of an object. Finally, there was a limit of objects allowed to be placed into a patch (i.e., an area of terrain) in Unity. It appears an upper-limit was based on vertices; given our terrain settings, this was an issue.

A limiter of fidelity was also calculated for the Unity environments. The most common way to attribute height vertices is to import a grayscale heightmap that represents individual heights of the terrain as a two-dimensional array of 16-bit grayscale values. This means that a single terrain tile can have a maximum representative range of 2^{16} or 65,536 discrete values at any one location in the 2D array. Current implementations of Unity support a maximum density of 4,096+1 for the heightmap. This limitation means that any grayscale-based terrain region represented by Unity's system must fit within this restriction. Selecting our terrain's ideal resolution to be of 1cm quality for each of our possible grayscale values, we find that our lowest-to-highest range spans a maximum distance of 655.36m for a single terrain tile. If we are representing an urban, fairly flat environment, this limitation is less concerning. Representing hilly, or excessively rugged terrain would require subdividing the tiles into very small segments. We summarise the relationship between desired game engine representation, in terms of representation fidelity of the terrain, as:

$$Ed = \frac{F}{2^{16}} \tag{1}$$

$$Ma = (4{,}097F)^2 \tag{2}$$

In equation (1) Ed is the elevation delta with the fidelity of F. Equation (2) shows the relationship between the maximum area, Ma, and the desired fidelity of representing the area expressed as a function of the maximum Unity grayscale heightmap and the desired representational fidelity. Overall, the limitation of the 16-bit representation of depth and 4,097*4,097 resolution limitation can be constraining when attempting to preserve the highest possible RW representation within the game engine. The University of Central Florida Institute for Simulation and Training (or simply, IST) has begun implementation of a Unity terrain importer capable of preserving the original sensor fidelity. The importer bridges the gap between traditional geospatial source data and Unity terrain objects. The importer ingests 3D formats generally associated with 3D models (including OBJ, FBX, and DAE), which are then translated into the native Unity terrain tiles.

2.2. Experimental Procedure Summary

The overall procedure for the experiment followed a linear, stepwise process:

1. The physical data of the RW environment were collected via images.
2. The physical data of the RW environment were used to generate a point cloud.
3. The point cloud was converted to polygonal meshes.
4. The polygonal meshes were imported into the Unity game engine as part of a SNE.
5. The SNE, as a section, was used as training fodder for a deep learning model.
6. The deep learning model's decisions were used to infer and place game objects into the remaining section of the SNE.

2.3. Data Collection Process

Sensors, such as LiDAR and software photogrammetric techniques, are established sources for dense point-cloud collection. The dense point-cloud data sources can be fused from low-flying aerial platforms, ground systems, or satellite-based multi-spectral sensors. For the present dataset, a Man-Wearable System (MWS) and a low-flying drone were leveraged to generate a high-density point-cloud representation of a real Army training range, located at Aberdeen Proving Grounds, Maryland.

2.3.1. Drone Data Capture

The U.S. Army Futures Command, Combat Capability Development Command-Soldier Center (known as the Simulation and Training Technology Center (STTC)) and IST, in cooperation with a small business, Micro Aerial Projects, implemented a medium-frame UAS for high-quality data acquisition. IST assembled, tested, and instrumented a quad-propeller, semi-autonomous UAS for rapid data collection that complied with Federal Aviation Administration Guidelines (Part 107) and implemented full control over both part source and traceability of the onboard PixHawk flight controller. The overriding goal was to collect the highest quality, georeferenced photos as possible. IST leveraged the Micro Aerial V-Map system along with the highest quality camera available at the time, the SONY-A7RII. The V-Map system, which leveraged Real-Time Kinematic (RTK) GPS, was used to collect the large majority of the RW training range. The V-Map system allows correlation accuracy of 10mm on the horizontal axis and 15mm on the vertical axis (Micro Aerial Projects L.L.C. n. d.).

IST flew the UAS at the height of 50 meters, then again at the height of 40 meters, to collect the imagery in the focal length of the sensor and lens configuration of the A7R-II. Each run was flown in orthogonal vectors to ensure maximum sensor overlap.

2.3.2. Man Wearable System (MWS)

To supplement the drone capture, IST built a man-wearable photogrammetry system: using the MWS (see Figure 2), areas that were inaccessible by traditional drone collection method were able to be collected. The MWS enabled data collection under low-hanging canopies, under power lines, and around interiors. The system auto-triggers the Sony A7R-II camera based on movement derived from a Pixie RTK GPS. The percentage of overlap between photos can be entered by the user into the mobile-computing platform's display. Based on the requested overlap, the georeferenced photos are automatically triggered by the MWS software, based on the distance trajectory being tracked on the embedded computer. The MWS was based on a gimbal and had a jitter-eliminating pendulum and metal-armed frame to reduce motion blur introduced by normal walking. The images obtained with the MWS are georeferenced by recoding the RTK GPS location, heading, velocity, and time attributes along with the photographs. Accuracy was improved by including ground control points to minimise registration and camera trajectory errors in the post-processing software. Both PhotoScan and RealityCapture software were used to generate photogrammetric-derived dense point-clouds for merging into the dataset provided by the UAS.

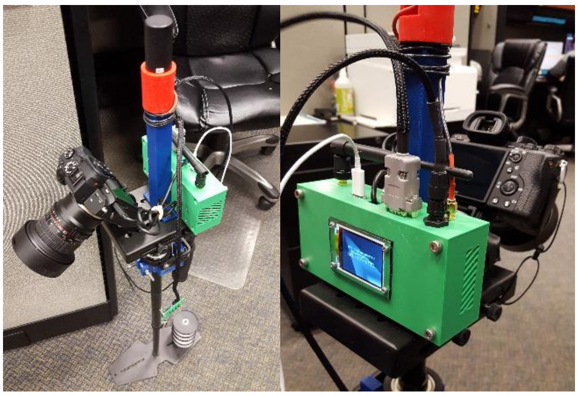

Figure 2: The Man Wearable System (MWS) From Different Angles

2.4. Dense Point Cloud to Polygonal Mesh Conversion

To visualise point-cloud data in a game engine, the generated point cloud must be processed into a polygonal mesh. Unfortunately, the resultant initial mesh can be extremely dense, leading to very realistic but less efficient—terrain (especially on mobile or embedded training devices). For example, one berm at full resolution could be represented by over 25,000 triangles, once converted from a dense point-cloud into a mesh. Having multiple berms across a terrain would quickly hinder the framerate.

Typically, the quality of the final model is increased when beginning with a very dense model and working down to a low polygon model. As part of the optimisation process, the full resolution mesh was decimated until an acceptable balance between polygon count and fidelity was reached. Textures and normal maps created from the high-resolution mesh can aid in keeping a visually realistic model with a low polygon count. Ultimately, decimating in a stepwise fashion (e.g. decimating by 10% five times, instead of 50% one time) was found to produce a higher quality and more accurate decimated mesh. There are times that the high-resolution mesh needs to be re-topologised to allow for a quality decimation process; this is especially true if you have parts of a mesh that need to move, such as a door or a person's facial features. Sometimes the UVs (or two-dimensional texture coordinates) require manual modification in an external program, such as Photoshop.

2.5. Terrain Vs. Game Object Vs. Game Object Modelisation

Based on the desired use case, there are technical limitations to consider when trying to develop the high-fidelity environments needed for live training. Even though our data collection process allowed us to create an extremely detailed mesh that represents the real world very well, using all of that data in a training system is not realistic, because of computer performance implications. Therefore, a design choice includes replacing mesh objects (e.g., trees, buildings, vehicles), which were generated from point-clouds of the RW, with similar highly-optimised models. Ideally, a system could learn and recognise objects using RW data, find the best object replacement from a catalogue of optimised models, and place-and-fit the model correctly. These optimised models would fall somewhere between geotypical and geospecific, and would thus be geospecifical. This novel system would learn-and-classify streamed RW data, and then populate a training environment with highly optimised geospecifical models that closely match the RW data. This system would allow for the rapid creation of high-fidelity environments that are optimised to run on training devices.

2.6. Essential Model Training

A deep learning model was built to detect berms in the SNE automatically. For deep learning, the berms in the SNE were tagged and localised in order to build a dataset of ground-truth berms. Within Unity, berms were tagged with the berm class name and a game-object bounding box: an automated training session captured images of these objects at several different positions. Since the end application necessitated aerial detection of these objects, our training session captured dataset images from an aerial view. Ground-truth labels were also generated by calculating the image coordinates from the game objects' world coordinates.

After the SNE dataset was generated, the dataset was segmented into training, validation, and testing subsets: the percentage splits were 60:20:20 over a dataset of 267,300 images. The segmentation was used to provide datasets from the same domain that could be used for testing, validation, and training of the model. This segmentation prevents the model from being tested on images from which the model was originally trained. If a model is both trained and tested on the same dataset, then the model would be influenced to memorise the dataset.

A secondary dataset, which removed all game-object models from the scene, was also generated in order to identify any influence stemming from the additionally placed models.

The next step was to train the deep neural network model. In this case, the You Only Look Once (YOLOV3) model proved best, due to both its end-to-end network and its speed during inference. The model was trained using standard hyper-parameters provided in the YOLOV3-608 network configuration. Afterwards, the learned weights were visually tested for accuracy (see Figures 3 and 4 for an example of the detection). The findings suggested weights trained after 20,000 iterations provided reasonable results.

Figure 3: Example of Trained Model Output Detection

The selected weights were then evaluated on the testing subset of the generated dataset. The measure of performance of our model was determined through a precision-versus-recall curve. Precision indicates the ratio of correct detections as compared to total detections. Recall indicates the ratio of correct detections as compared to the total possible correct labels. Both precision and recall are functions of the intersection-over-union and a prediction-confidence threshold calculation. The intersection-over-union is the percentage of our two bounding boxes' (i.e., the ground-truth bounding box and the predicted bounding box)

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overlap, over the total shared area. The resulting model's behaviour can be determined by plotting the results of precision and recall, as the intersection-over-union threshold is changed. The change in the threshold illustrates the design decision of requiring high precision, versus requiring more inclusivity, when using our trained model.

Figure 4: Example of Trained Model Output Detection

3. RESULTS

3.1. Precision and Recall Results

Figure 5 describes the behaviour of the trained model in terms of precision and recall for several trained weights when evaluated on a test dataset. The trained weights are labelled by the number of epochs of training that had occurred.

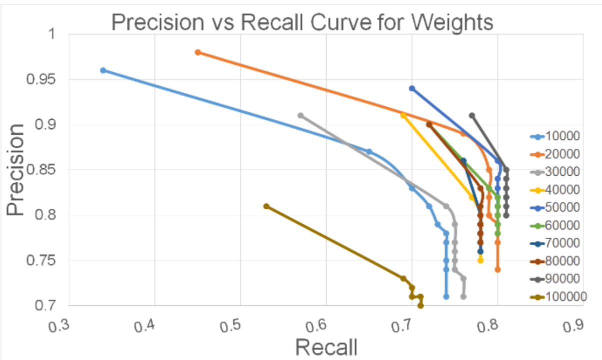

Figure 5: Graph of Precision and Recall, Showing Success of Deep Learning Algorithm

The 20,000 weight curve shows a model behaviour with a precision maximum of 0.98, but a corresponding recall of 0.45. The average precision of the 20,000 weight curve is 0.825. Conversely, the 90,000 weight curve produces maximum recall values of 0.81, but has a corresponding precision of 0.85. The average precision of the 90,000 weight curve is 0.833.

For a balanced approach, we can see that 20,000, 60,000, 80,000, and 90,000 weights produce precision values of approximately 0.90 and recall values of approximately 0.78 at a prediction threshold value of 0.99.

The secondary dataset results are in line with the results, as mentioned earlier. The 20,000 weight curve reveals a maximum precision of 0.98 and recall of 0.45 for a threshold value of 0.99. The 90,000 weight curve shows a maximum recall of 0.81 and precision of 0.85. This shows a nearly identical relation to the above dataset's results.

3.2. Analysis of Results

The questions of which weight to use in the final model will be dependent on the inference dataset that will be seen. As the inference dataset moves further away from our training domain, we would use a less-trained model to have a greater generalisation property.

Given our current test set, our results indicate that further training may not produce any statistically significant benefits; this idea is backed by a calculated standard deviation of 0.047 for precision and 0.067 for recall across all reported weights.

We can also see that model precision and recall values seem to be oscillating as the weights increase. This might be indicative of a local or a global minima within our inherent model distribution function. If this is, in fact, a local minima, further training with a larger learning rate may help escape this issue. Any further model performance increase will need to stem from training, tuning, or dataset augmentation. If this is due to a global minima, then overall changes, such as an expanded or augmented dataset, or a new model, would need to be implemented in order to provide a tangible performance difference.

The values of precision and recall are not unexpected, considering how the domain distance of the training, validation, and testing sets are small; and how YOLOV3-608 reported a mean average precision score of 0.579 when tested on the MS-COCO dataset. Since we are focusing on a single object, as opposed to the eighty classes in the MS-COCO dataset, we can expect to see an increase in average precision over the reported results.

Our secondary dataset produced nearly identical precision-recall curves to the initial dataset. The difference between the two are not statistically significant and can be attributed to the stochastic nature of training the model and the differences in the dataset. We can safely conclude that the additions of vegetation and building models did not significantly contribute to the performance of our model.

The performance of the model indicates that classification on images collected from a SNE can be used to provide accurate detection of terrain objects. This, in turn, provides a feasibility confirmation for applications reliant on the object detection of these terrain objects. Our reported level of recall is reasonable for applications that require total coverage of objects of interest. Also, the level of precision supports applications that require exact detections.

4. DISCUSSION

The goal of this work was to examine the potential capabilities of deep learning object detection on the terrain domain. The object class selected for the detection task is one that may prove difficult due to its similarity to surrounding terrain and rocky surfaces. As we can see in Figure 6, our trained model may not always correctly identify the berm object.

As we can see from our analysis, our model performance can provide fairly accurate detections through the use of a simple data collection session. Given the success and difficulty of this class's detection, we can expect to expand to other more distinctive classes with reasonable success. This work is intended to lay the groundwork for future terrain generation applications that can scale to hundreds, if not thousands, of classes with little additional manual effort and with competitive performance, regardless of need.

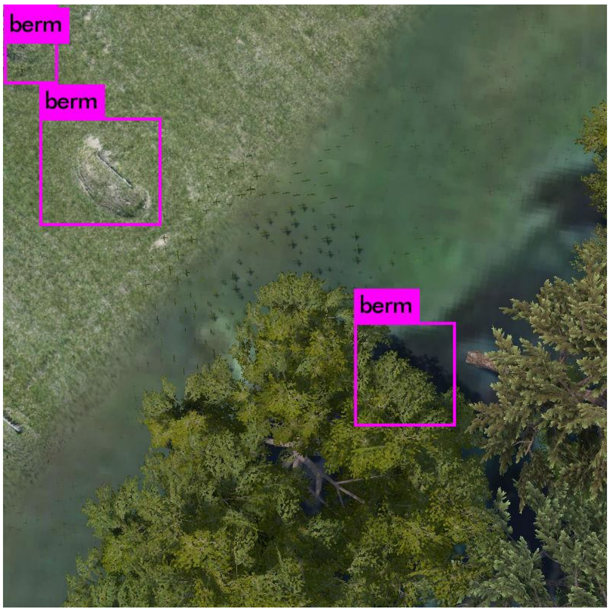

Figure 6: Example of False Positive Detection

5. CONCLUSION

Training simulations may benefit from realistic SNEs; yet effectively and efficiently creating these environments to match the RW has been a challenge. In this paper, a current terrain import limitation of the Unity game engine was discussed, as well as an in-progress solution. Additionally, this paper used a deep learning algorithm to support the automated re-creation, or reconstruction, of RW environments. Ultimately, the results suggest that the methodology of applying a combination of photogrammetry and 3D scanning can generate a high-fidelity SNE that can then be used to accurately train a deep learning object detection model to populate the said environment with detected classes. This pipeline can be scaled to hold several more classes and cut the cost of labour for high-fidelity SNE generation.

5.1. Limitations

The largest hurdle with the present methodology is the initial model training. To create the final model, one must first train the model with classes of interest. This requires an initial identification and data-capture process in the SNE. After the model is trained on the captured data, the model can then be used to infer on a production dataset. This can be mitigated and pre-trained for common terrain objects, such as trees, flowers, and berms; but more specialised classes may require additional training.

The training process usually requires a large number of images per classes for accurate detection. This process can also be reduced by training on top of our pre-trained model, and by data augmentation techniques, such as rotations, which can be integrated into the data capture session. Future research into other one-shot learning techniques can further reduce the impact of this issue.

After the model has been trained and provided detections, the issue of the dataset's domain can arise. For example, if we train based on berms in a grassy field, and then infer on berms in a snowfield, we can expect a decrease in performance. This is an issue intrinsic to any model: the model will predict based only on what it has seen. The main solution to this issue is to provide a continuous training pipeline to teach the model whenever it encounters new data, predicts false positives, or predicts false negatives. Rough estimation techniques and dataset tools can help human annotators identify these issues. Future research into adversarial networks or actor-critic networks can potentially lead to solutions that ease or replace the human labour of this issue.

Consideration of ill-intentioned individuals in the military domain is a requirement when researching technologies that will be heavily relied on. The act of intentionally fooling a neural network is an active area of research and growing security concerns. YOLOV2 was shown to be susceptible to an adversarial attack (Thys, Van Ranst, and Goedemé 2019). These sorts of attacks are difficult to predict and respond to. This problem is a special case of a model receiving never-before-seen data and not predicting the correct response. The solution to this has been to provide data of the false positives and false negatives or to tune the model's level of discrimination through the allowable thresholding.

5.2. Future Research

As a next step, choosing the appropriate form of a machine-learning algorithm will be valuable; one variant of machine learning to investigate is one-shot learning. The one-shot learning technique in machine learning is used to quickly train a model on a new class using only a few training images. The difficulty of this method comes from the model's inability to reflect on past-learnt classes and find similarities to new classes, in order to rapidly learn. The adoption and research of this technique can help scale models to new classes greatly.

The present experiment focused on testing the training and classification of one type of feature: a berm. Given the diversity of RW environments, a larger range of class types should be considered in future deep learning train-and-test paradigms.

In conjunction, if game engines in military training are to become accepted as valuable in terrain reconstruction, building advantage profiles per each system (e.g., Unity, Unreal, and CryEngine) is desired: defining which game engines are most effective and efficient at building SNEs should be considered.

Further, IST is developing a method to allow direct import of 3D mesh files (e.g., OBJ and FBX) to be losslessly reinterpreted as native Unity terrain (see Figure 7). This solution eliminates the need to use a 16-bit depth heightmap. While not fully mature, this solution deserves further research.

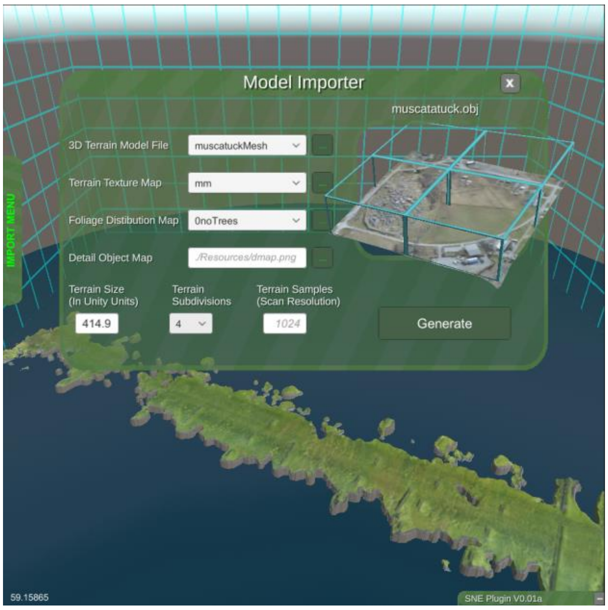

Figure 7: Screenshot of the Unity Terrain Importer

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ESTABLISHING A MESH COMMUNICATION BACKBONE FOR DISASTER MANAGEMENT: PROOF OF CONCEPT

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ABSTRACT

This article addresses the establishment of a mesh communication backbone to facilitate a near real-time and seamless communications channel for disaster data management at its proof of concept stage. A complete function of the data communications is aimed at the input in near real-time of texts, photos, live HD videos of the incident to originate the disaster data management of a military unit responsible for prevention and solving disaster problems and in need of a communication backbone that links data from a Response Unit to an Incident Command Station. The functions of data flow were tested in lab and at fields. Texts encompassing registered name, latitude, longitude, sent time were sent from concurrent 6 responders. Photos and full HD live videos were successfully sent to a laptop Incident Command Station. However, a disaster database management system was needed to store data sent by the Response Unit. Quantitative statistics were suggested for a more substantial proof of concept and subject to further studies.

Keywords: Disaster management**,** proof of concept**,** mesh communication**,** communication backbone

1. INTRODUCTION

Shannon and Weaver (1949) invented the model of communication, known as the “Shannon and Weaver model of communication”, to get a message from one point to another in discovering how communication messages could be converted into electronic signals most efficiently, and how those signals could be transmitted with a minimum of error. A reliable communication backbone is regarded as a crucial infrastructure to the interface and integration of standard electronic devices for the message transmission and to the better situation awareness of the destination. Ran and Nedovic-Budic (2016) reported the integration of spatial planning with flood-risk management to gain prominence as an approach to mitigating the risks of flooding. The approach was reported to be impeded by the absence of easy access to integrated and high-quality information, and the technologies and tools to use information. To facilitate the integration, a Spatially Integrated Policy Infrastructure (SIPI) was conceptualized for an integrated spatial planning with flood-risk management should encompass three elements: (1) data and information, (2) decision support and scientific analysis tools, and (3) access tools and protocols.

Figure 1: An operational view of the mesh communication backbone

Kumsap (2018) proposed the concept of mobile C[4]ISR (Command, Control, Communication, Computer, Intelligence, Surveillance, Reconnaissance) system for disaster relief. The preparedness could be achieved by UAV terrain modeling over a frequently flooded area in normal situation. The product of image acquisition e.g., orthoimages, digital terrain models and updated ground survey, is integrally developing a platform to host data and information from reconnaissance and emergency response for situation awareness in common operating picture (COP). Activities reported in form of texts, photos, video clips as far away as 150 kilometers from the mobile C[4]ISR are live broadcast by an Unmanned Aerial Station hovering at 3,000 meters above the Response Unit. Kumsap et al (2017) explained the project in which the mobile C[4]ISR was implemented in the Defence Technology Institute that implemented the integration of communications, military simulation and training, and unmanned vehicle technologies for the emerging situation awareness to be viewed from the COP.

Back in 2012, the Royal Thai Government, in conjuncttion with the World Bank and other development partners, undertook the rapid assessment of the impact of the floods in 26 of the 66 affected provinces. It provided recommendations for resilient recovery and reconstruct where the continuation of broadcasting to all communities before, during and after disasters should be ensured. In this respect, it was suggested to improve communication from the National Early Warning Center to the broadcasters and engage broadcasts around disaster risk reduction. Such radio community could provide communications in disaster preparedness, disaster response and relief and post-disaster communications in accordance with their community needs. In Ali et al (2014), they proposed a novel Integer Linear Programming (ILP) optimization model to reconstruct the optimal connected mesh backbone topology with a minimum number of links and relay nodes which satisfies the given end-to-end QoS demands for multimedia traffic and identification of extra resources, while maintaining redundancy. Although the reconstructed optimized backbone mesh topology also maintained the specific level of redundancy, the study only considered single-path routing between source and destination pairs. The work should be further extended to multipath routing between source and destination pairs. Wan and Zlatanova (2016) presented an approach for using a multi-agent system for navigating one or multiple responders to one or multiple destinations in the presence of moving obstacles. A set of software agents was designed and developed to support the spatial data processing and analysis involved in the routing process. There still needed considerations for future developments, one of which was the real time positions of the relief vehicles. Because the communication infrastructure may not be available or work properly during a disaster response, a decentralized method is needed to allow negotiations among different users.

In Khaliq et al (2019), a Vehicular Ad Hoc Network (VANET) was used to carry out the rescue operation, as it did not require any pre-existing infrastructure. The work proposed and validated an effective way to relay the crucial information through the development of an application and the deployment of an experimental TestBed in a vehicular environment. The performance of the system was analyzed in terms of response time, successful data transmission, and delay. The proposed prototype application was examined through experimental validation by fetching the user message from the GPIO pins of the Raspberry Pi through serial communication, and the geographical coordinates of the user from the GPS sensor. This study, along with the implemented TestBed, provided an effective way to exchange crucial information amongst volunteers and staff working in dire situations, such as that of a post-disaster rescue-and-relief operation. Since fast and reliable communication plays a key role in such scenarios, this work offered a viable solution that can be implemented by the concerned authorities at times of catastrophic disaster. Wireless ad hoc networks such as mobile ad hoc networks, wireless sensor networks and wireless mesh networks were the promising alternatives in situations of disaster communication. Channa and Ahmed (2019) presented a survey of the proposed emergency response communication frameworks and the potential security services required by them to provide reliable and secure information exchange during emergency situations. The majority of the proposed schemes lacked the security services required for reliable and secure information exchange. The key security services included privacy, data integrity, authentication, key management and access control.

This article addresses an experimental proof of concept of the establishment of a mesh communication to form a near real-time, crucial and seamless communications channel for disaster data management that may be unavailable of malfunctioned due to disaster incidents for the Mobile Development Unit 31 (MDU 31) located at Northern Nan province. The MDU 31 is one of five Units under the Third Armed Forces Development Command at Chiang Mai province (the 3rd AFDC). Under the supervision of the 3rd AFDC, the MDU 31 is responsible for prevention and solving disaster problems and humanitarian assistance. The MDU 31 response units are dependent upon a commercial and costly network coverage for data communications and in need of the communications backbone that establishes freely accessible yet secure data links from the Response Unit to the Incident Command Station. Therefore, the objective of this current work is to report proof of concept of the establishment of the mesh communication backbone for disaster data management by experiments in laboratory and at field in support of decision making processes upon the disaster management of the MDU 31.

2. SUB-SYUSTEMS OF MESH COMMUNICATION BACKBONE

To closely resemble the theory by Shannon Weaver model and adopt the data flow proposed by Kumsap (2018), the operational view of the mesh communications backbone was initiated to facilitate the injection of disaster data including geo-tagged photos, geolocations and video clips on the data flow. The Response Unit injects data into the flow to start the mission while management at the Command and Control station receives information to make a decision and feeds the command back to the data communication flow. Each node of operation is functional as follows:

2.1. Response Unit

A response team of 12 military officers is equipped with 6 smartphones to feed in photos, request texts, map locations and video clips to the flow with the man pack as data portal. The 2 Mbps data throughput, 2W Tx power man pack receives GPS signal, sends .txt, .csv log files in real time and accommodates IP camera type video signals. This originates the disaster management with the man pack joining the network to act as the portal of data input.

2.2. Unmanned Aerial Station

Apart from the radio device for flight control, the unmanned vehicle is equipped with a two-way communication, 1.4 – 2.4 GHz, 10W transmission power, 2-8 Mbps receiving radio broadcast device. It is an aerial node to relay the data at approximately 9,000 feet above or away from the Response Unit. The communication is alive at 30 – 150 kilometers from the

Incident Command Station (see Figure 1). The unmanned vehicle is gasoline – fueled and capable of 6 hour endurance.

2.3. Incident Command Station

The mobile command station is now being developed to house high-performance computational work stations and servers. A grid antenna is attached to receive and transmit data into and out of a 10 Mbps bandwidth, 1.4 – 2.4 GHz frequency and 10W Tx/Rx device. The modeling, analysis and simulation of the data received from the Response Unit is performed at this node that is stationed remotely up to 150 kilometers away from the incident area and with easy access to an active communication channel.

2.4. Command and Control Station

This data destination is equipped with capacity where intelligence is produced upon the information visualization and situation awareness of 3D common operating pictures. A decision support system with serious game engine is the back office of this station and planned to take shape in Thailand's 2020 fiscal year. Standard operating procedure (SOP) of damage assessment, forcible entry, victim search, rescue and saving life, and evacuation is product of the *Station*'s disaster management and sent back to the response team in form of optimum routes and SOP.

3. DATA INJECTION AT THE RESPONSE UNIT

Kumsap et al (2018) proposed the enhancement of disaster preparedness and response by setting up the system to support the disaster recovery team in case of wide-area communication blackout caused by flooding, earthquakes or any large-scale accidents. The notion was based on today system communications that are digital and IP-based with a wide variety of data communications such as voice, video or other bandwidth-greedy information, occupying lots of bandwidth ranges while requiring stable transmission. Mesh topology was adopted to relay data between each node, thus improving the system latency. The backbone was regarded as an infrastructure that needs a portal to input disaster data. The data including geo-tagged photos, geo-locations and video clips was used to start the disaster report from an incident site, i.e., being injected to the Response Unit, being relayed at the Unmanned Aerial Station, being analyzed at the Incident Command Station, and being managed under a decision making process at the Command and Control center. This current approach promises integral technologies such as the unmanned aerial station for signal relay, man pack radio networked with smartphones for response unit, mobile incident command for spatial analysis and networking fielded missions with the command and control station. The implementation of the proposed methodology can be seen on Mesh Backbone diagram of Figure 2.

At Network diagram of Figure 2, six smartphones with mobile application for disaster report are to inject data including texted report in .txt or .asci; geo-tagged photos in .jpeg, .tif or .geotif; and video clips in .flv, .avi, .mov, .wmv or .mp4**.** into a rugged notebook for storage via a wireless access point connected with the man pack. Designed and implemented specifically for the military performing task at the Response Unit, this data input portal was exclusive for the military Response Unit. The situation awareness and common views of the command center and the response team demand a closed system of the backbone. However, the Command and Control Station would manage in-coming data from the public and can be reached by the public in general for the purpose of disaster response or public disaster report. The data is transmitted to the Tx/Rx device onboard the aerial station within the 9,000 foot range of the man pack. The data received at the Incident Command station is further analyzed in an image and video processing server environment. The result information is sent to the Command and Control station through an existing communication infrastructure. Decision making upon damage assessment, forcible entry, victim search, rescue and saving life, and evacuation is sent back to command the mission in reverse of the previously explained data flow.

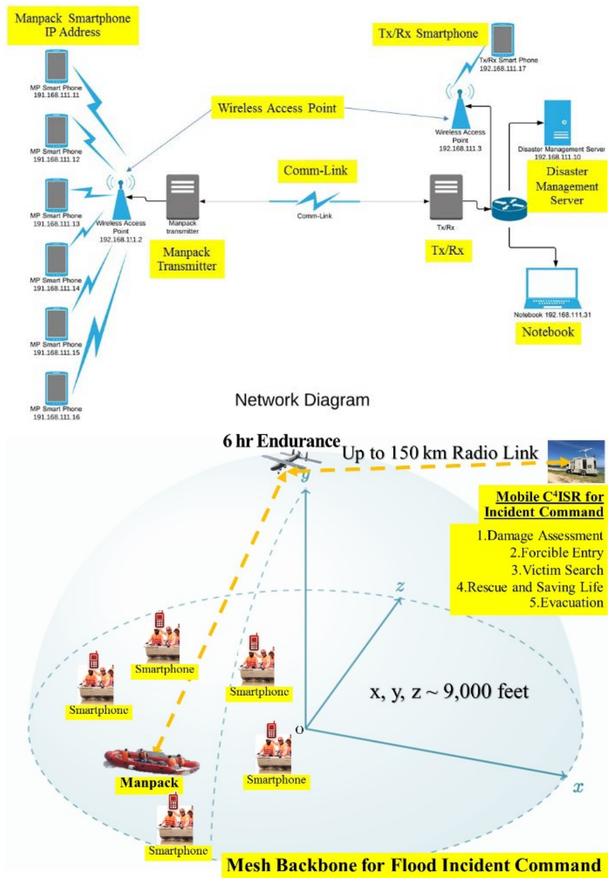

Figure 2: Network diagram for conceptual design and mesh backbone for operational design

4. EXPERIMENT ON DATA INJECTION TO THE BACKBONE

In order to proof the concept, a few experiments were carried out to test a simplified architecture extracted from the data flow diagram in a laboratory and at fields with and without a flood incident. However, the test conducted in the laboratory was with the 6 smart phones and without the unmanned relay station. The field tests were with to send texts of map coordinate, geo-tagged photos, and a live full HD video to the notebook that acted as the Incident Command Station.

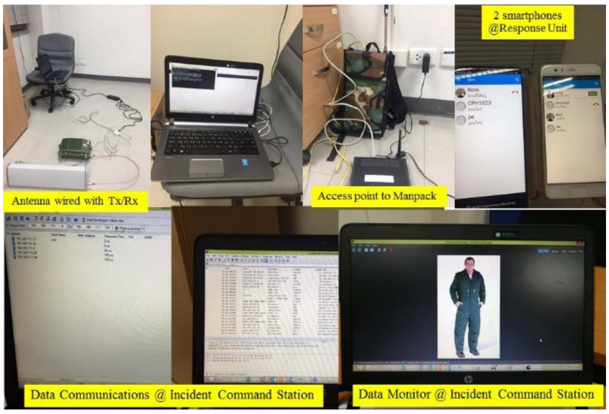

Figure 3: Rough interface of the network backbone

4.1. Laboratory Test

In reference to the Network Diagram of Figure 2, the hardware was networked as illustrated in Figure 3. The smartphones installed with a mobile application were used to send texts, photos and video clips with one another via an access point wired with the man pack through to the notebook as a data monitor at the Incident Command Station. Data communications between the smartphones and the notebook acting as a workstation were tested at as far as 50 meters. All the smartphones were used to concurrently send texts, photos and full live video to proof the 24 Mbps bandwidth handling of the man pack. Live chats were also tried among the smartphones and between each of them and the notebook, see the lower right inset of Figure 3.

4.2. Field Tests

Normal Situation Testbed. The system was setup at various locations in the Northern part of Thailand. A generator (see the upper left inset of Figure 4) was used to produce power for the Tx/Rx device, antenna and the notebook that managed to chat live with the Response Unit. The Incident Command Station was mobile and compact. Map locations of an activity were periodically reported back to the station in 10 second interval with the most recent being plotted on the map (see the lower left inset of Figure 4). Photos were sent at will as far as 2 kilometers between the man pack and the Incident Command (see the lower right inset of Figure 4). Two hundred meters were the distance that the smartphone being used as the video and photo source was visible to the man pack. The communications were active regardless of rough and vegetated terrain provided that the antenna was directed toward the Response Unit in operation. The structured text to send report from the response unit is now being developed in the lab.
In addition, the system was tested for functions of sending texts, photos and video at the MDU 31. The man pack and the Tx/Rx device acted as nodes for the communications backbone to receive and send the communicated data from and to one another, forming a near real-time, crucial and seamless communications channel.

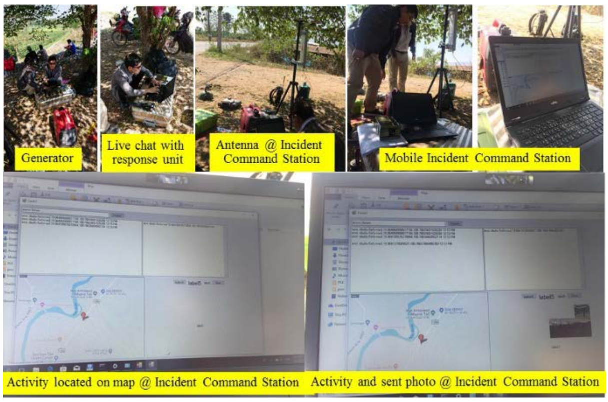

Figure 4: Configuration of the established backbone

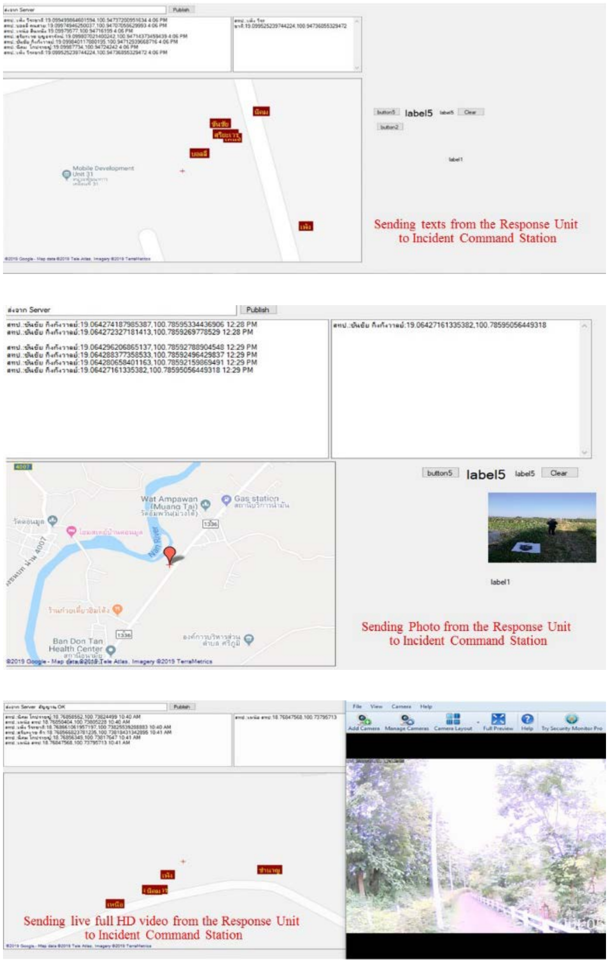

Figure 5: Field test results of sending texts, photos and video

Therefore, this is regarded as prime contribution to disaster data management that keeps the Response Unit and the Incident Command Station stay connected due to the unavailability and malfunction of communications due to disaster incidents for the MDU 31. The six smartphones were connected to an access point that was attached to and powered by the man pack. The response team of 6 persons moved as a group in order to stay at least 50 meters away from the access point for data communications. A text formatted in Thai of DTI, registered USER NAME, LATITUDE, LONGI-TUDE, TIME (see the topmost inset of Figure 5) was sent via the access point to the man pack and finally to the antenna connected to the Tx/Rx device where the laptop was used to respond back in text to the response team. Geo-tagged photos were successfully sent (see the middle inset of Figure 5) to the laptop in the same manner as texts but at manual operation. The photos were coded at the smart-phone and decoded at the laptop, easing the need to occupy much of the bandwidth during the data sending. However, the test of live full HD video (see the lower inset of Figure 5) was performed on only one smartphone and successfully attained at the required live operation and seamless data communication.

5. RESULTS AND DISCUSSION

The mesh communication backbone regarded in this work as the channel for the data to flow smoothly from the Response Unit through to the Incident Command Station despite the unavailability or damaged communi-cation channel. The MDU 31 response units previously dependent upon the commercial and network coverage for the data communications was promised with the proposed communications backbone that established free access to the data links and communications back and forth between the Response Unit to the Incident Com-mand Station. Therefore, the objective of this work on proof of concept of the establishment of the mesh communication backbone for disaster data management of the MDU 31 was fully implemented and successfully tested in the lab and at the field. The text formatted in Thai was illustrated to prove the data sending by the response team and from the incident commander. The geo-tagged photos could be successfully sent to the laptop at manual operation without bandwidth occupa-tion at all times by coding and decoding measures. The test of live full HD video was performed by one responder to attain the live operation and seamless data communication. Two hundred meters were the distance that the smartphones being used as the video and photo source were visible to the directed antenna. The ten second interval was followed to update the geo-locations of locations of the response team. However, an automatic storage of data was needed to manage the transmitted data and accumulate the disaster database management system of the MDU 31.

Quantitative statistics were a more substantial proof of concept and subject to further address after the Unmanned Aerial Station and Command and Control are introduced to the system. The generator caused signal fluctuation upon system's power provision in the Normal Situation Testbed, subject to retest in a complete team of the Response Unit for the disaster database management and with the live chat and data communications for system latency and stability. The map previously used to base locations of the activity is subject to replacement with the acquired, geo-referenced images from the used drone to form a common picture for the disaster management. In addition, signal propagation from the directional antenna empirically achieved with manual adjustment of the antenna was reckoned to be more problematic with the Unmanned Aerial Station intro-duced to the system, not yet tested for this proof of concept. With the more stable source of power, the Flooded Situation Testbed results proved viable several aspects of the established mesh communication backbone; the completely versatile source of power to feed the system, the portable man pack requiring only one operator, the almost all obstacle-free propagation of signal transmission and receiving, and the powerful device for up to 2 kilometers of data communications regardless of rough and vegetated terrain. There is room for improvement on stabilized video being fed live to Incident Command Station to avoid dizziness from video watching. Bandwidth occupation for text messages, photos and video clips needs further studies to manage the reserved and available bandwidth with help from mesh networking.

There were limitations hindering the complete proof of concept for the real establishment of the mesh communication backbone. The uninstalled but assumed Unmanned Aerial Station ideally aimed at 9,000 feet was tested only horizontally away from the Response Unit. Another field test with the unmanned equipment hovering above was planned to take place in a few months from this publication, being expected to form another novel publication. Six smartphones being concurrently networked to validate proper commu-nications and bandwidth management, being another limitation of this current work, were scheduled to co-exist in the same field test. The other limitation realized and obvious from this proof of concept was the map for situation awareness and display of tasked activities in the field, which would start and enable disaster management at the Incident Command Station. It was mentioned in the operational design on Figure 3 in include *Damage Assessment, Forcible Entry, Victim Search, Rescue and Saving Life, Evacuation* and subject to further investigation at the final stage of the entire project.

6. CONCLUSION AND RECOMMENDATIONS

This article addresses the proof of concept in establishing the mesh communication backbone for the MDU 31 response units to perform tasks independently of the commercial and network coverage for the data commu-nications. The Shannon Weaver model of communica-tion was followed to formulate the flow of data back and forth between the Response Unit and the Command and Control Station. The communication devices and their capacity were elaborated with the Network diagram for the Response Unit being illustrated and the mesh communication backbone being depicted. The data com-munications between the Response Unit and the Incident Command Station in form of formatted texts, geo-tagged and live full HD video was evidence of successful addresses of the establishment of the communication

backbone for the near real-time and seamless communications channel of the MDU 31. The mobile application for the Response Unit is subject to further development since it will input text messages, geotagged photos and video clips to the system flow, thus provoking the decision making at the Command and Control station.
The power generation for electronic equipment was problematic and needed careful design and development of the mobile vehicle that will house functions at the Command and Control station. Empirically, up to 2 kilometers of data communications between the man pack and the Incident Command was achieved regardless of rough and vegetated terrain provided that an antenna was directed toward the Response Unit in operation. Mathematical equations to explain the bandwidth occupation are suggested to quantitatively prove the success of the established mesh communication backbone and its kind. Further introduction of Unmanned Aerial and Command and Control station to the data flow and communications has to be addressed to verify the complete mesh communication backbone. Eventually, the decision support system simulated by serious game engine at the Command and Control station is novel and unique to the disaster database management and worth further investigation.
The recommendations will be further studied to complete the DTI's HADR project. Further work includes the installation of the communications equipment on the UAV to fully integrate the Unmanned Aerial Station to the backbone. Investigation on the simulation of the mission according to the data flow. Another room for study is to concurrently manage six smartphones within the 2.4 Mbps bandwidth network with seamless communications and optimized bandwidth management. Last but not least, the military disaster management in form of SOPs encompassing *Damage Assessment, Forcible Entry, Victim Search, Rescue and Saving Life, Evacuation* will be further investigated at the final stage of the project.

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EUROPEAN SENSOR SYSTEM FOR CBRN APPLICATIONS

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ABSTRACT
The paper presents the analysis of the EU-SENSE project as an example of European Union (EU) response to global threats in the field of chemical attacks. CBRN risks are noticed by EU which tries to handle them via many different actions, among others by encouraging small and medium enterprises, applied researches centers, industry and academic research to actively take part in establishing systems, both in detection and training modules. The EU-SENSE project meets all these requirements, hence it is a perfect example for the analysis of this type of projects, especially in relation to the methodology of collection of user requirements and development of the definition of key performance parameters.

Keywords: EU-SENSE project, chemical agents, user requirements, key performance parameters

1. INTRODUCTION

Significant progress has been made in recent years to protect European citizens from CBRN risks. However, recent developments in Syria, Malaysia, and the United Kingdom give good reasons to believe that the hazard posed by chemical agents remains high and is evolving. In the case of listed countries and, more generally, Western civilization, international community has to struggle with the Islamic State – the first non-state actor which is intensively developing chemical warfare agents and has reached the point, where agents were combined with a projectile delivery system. After the loss of Mosul in June 2017, chemical attacks stopped, mainly because 'caliphate' was not able to establish any alternative production facilities. Unfortunately, according to U.S. intelligence, cited by Columb Strack – analyst specializing in political and security risk forecasting for the Middle East, Islamic State has been set up a new chemical weapons cell in the Euphrates River Valley. This and other efforts in using and preparing chemical agents in combination with the specificity of modern fundamentalist terrorism give strong possibility that the group could export chemical terror to the West, among others by unmanned aerial vehicles (UAVs) and vehicle-borne improvised explosive devices (VBIEDs) (Strack, 2017). Furthermore, with reference to terrorists attacks in Europe, post-attack analysis pointed out that chemical substances were produced and bought in one country and sent to one of EU country where the attacks were executed. Moreover Interpol reported that numerous of CBRN materials were tried to gain or smuggle all over the world – the example of Litvinenko poisoning had shown that dangerous, radiological materials are still difficult to detect in EU (European Commission, 2014).

In addition to these extremely difficult challenges, there are still substantial shortcomings in, e.g., detection technologies in the different areas of public security. Fast and robust detection of an incident is paramount in order to safeguard the life and health of the population. The ability to rapidly detect CBRN incidents equates to faster response times, reduced hazard exposure, and more efficient use of limited resources. This kind of position is taken by EU and enriches it by adding more elements. For instance, according to reports under the EU CBRN Action Plan and the Action Plan on Enhancing the Security of Explosives in 2012, a new CBRN-E Agenda concentrates on improvement risk assessment, defines best practises in safety and security standards and spreads knowledge about it.

The Agenda highlights that effective mitigation strategy should contains:

- The effectiveness and performance of existing equipment and processes;
- New threat substances;
- New *modus operandi* for attacks;
- New concealment methods to attempt to by-pass security controls; and
- New attack targets, such as soft targets, critical infrastructures, public areas, non-aviation areas (European Commission, 2014).

EU focuses on improving detection of risk, usage results of research, testing and validation, supporting action to awareness raising and leading training sessions and exercises. Cooperation of all stakeholders, including academia, private sector or civil authorities is crucial to aim the goals.

Furthermore, improved detection was identified as a high-priority capability need in the Catalogue of

Technologies published by the ENCIRCLE project (http://encircle-cbrn.eu/) as part of the EU Horizon 2020 RIA call SEC-05-DRS-2016-2017: Chemical, biological, radiological and nuclear (CBRN) cluster part b). In the Catalogue there was pointed out that it is highly desirable to develop and implement fast and reliable detectors which could be applied in the prevention or preparedness phase.

1.1. THE PURPOSE OF THE PAPER

In the view of global challenges and EU initiatives which were presented above, it is scientifically interesting to look at one of the European project in order to examine how it tries to cope with chemical agents detection. For the purpose of analysing it, there is crucial to ask research questions. First of all, the careful look at architecture of the chosen EU project will led to pay attention to each elements are important for European Union, and in further perspective to answer the question which functions and modes should complement the main core of these kind of projects. Secondly, it is key to be informed which components could build systems of chemical detection and how they affect one on the other. EU projects, such a lot of other kinds of initiatives, are limited by the amount of financing, technological and organizational measures – what is essential in case of small and medium enterprises. And, last but not least question, what sorts of the expectations have end users of these types of systems? Are they only interested in getting information on detected chemicals, or systems should perform more functions.

The article is based on a case study methodology, which was considered as the satisfy method of organizing the content of the paper and coming to final conclusions. Case study methodology is used for both descriptive and explanatory purposes, but generally it is more suited to address the questions how and why, (than who, what and where), which are explanatory in nature. Because of the combination of the two characteristics indicated above, case study is especially essential for this paper. Moreover, the method supports studies which are still limited and do not need the generality of the situation or phenomenon – it is of secondary importance (Runeson, Höst, 2009). The case study methodology is not a one ordered collection of methods and forms of conducting research. It is an extensive set of approaches that allows people to explore the surrounding reality. In fact, the variety of ways to use this method in most areas of knowledge proves its great potential in explaining both simple and repetitive phenomena, as well as complicated and ambiguous ones. Applying any method to scientific work makes a set of constraints and opportunities happen. According to Geoff Easton – a professor at Lancaster University, the main constraint on the case study is the low statistical representativeness, while the key opportunity is the real possibility of understanding a phenomenon in depth and comprehensively (Easton, 2010). In the paper both opposite indicators appear. On the one hand, the analysis of a single EU project allows for a more precise look at its architecture and functions. On the other hand, it limits the possibility of drawing extended, general conclusions. Instead of this, it enables the researchers to prepare only a preliminary generalization which could be useful to identify wider needs declared by the European Union or to compare different European projects in further studies.

Key and organizational question in the paper is: why the EU-SENSE project was chosen as the example of the European project in the subject of combating threats of chemical attacks. First of all, it is connected with the great experience of the members of the EU-SENSE consortium. Wide representation of the various entities helps to develop project in the practical, technical and scientific context. All members have also experience in conducting research and works in the frame of EU requirements, or at least according to national guidelines. Secondly, authors of the article are the members of the project's research team what gives them the deep insight into the procedures, goals and activities which are taken during this kind of projects. It also allows to look carefully at the architecture of the system and its functions, and in the longer term to compare them with the basic assumptions of the EU Horizon 2020 RIA call SEC-05-DRS-2016-2017: Chemical, biological, radiological and nuclear (CBRN) cluster part b).

2. EU-SENSE PROJECT AS A RESPONSE TO CHALLENGES IN THE FIELD OF CHEMICAL ATTACKS

As it was mentioned above, chemical agents could be the source of dangers for European societies, especially in case of Islamic State's activity. EU, similarly like Interpol, predicts that it becomes more and more important to support initiatives taken, among others, by industry SMEs (Small and medium-sized enterprises) as well as by academic and applied researches to provide an innovative technical solution to deal with chemical detection. The answer for Work programme topic called SEC-05-DRS-2016-2017: Chemical, biological, radio-logical and nuclear (CBRN) cluster part b) gave a chance for involving the indicated entities to actively take part in preparing a novel network of sensors which will be using advanced machine-learning and modeling algorithms for improved performance in chemical detection. The success of the proposal of nine members forming EU-SENSE project's consortium has opened up the possibility of creating a step-change in chemical detection as well as implementing a dedicated mode covering CBRN practitioners training needs. The following sections will focus on specific aspects of the EU-SENSE project what will allow to explain the EU attitude toward the challenges connected with detecting and combating CBRN risks, especially referring to chemical agents.

2.1. EU-SENSE OBJECTIVES AND CONCEPT

The EU-SENSE project seeks to address the high-priority gaps and needs within chemical detection by developing a novel network of sensors for CBRN applications through exploitation of novel chemical detector technologies, advanced machine-learning and modeling algorithms. Specifically, the EU-SENSE project pursue three high-levels objectives. First objective aims to contribute to better situational awareness of the CBRN practitioners through the development of a novel network of chemical sensors, which will provide a technological solution to relevant gaps presented in the ENCIRCLE catalogue of technologies (high-level objective 1). Second goal was setting to improve the detection capabilities of the novel network of chemical sensors through the use of machine learning algorithms to reduce the impact of environmental noise and the application of contaminant dispersion models (high-level objective 2). In the context of the second high-level objective, environmental noise means any signal arising from pollutants in the environment that can cause either false positive (danger indicated with no danger present) or false negative (dangers not indicated when danger present) detection results. The third high-level objective proposes to showcase the usability of the EU-SENSE network to CBRN practitioners in order to validate the system and to maximize its exploitation potential (Proposal of European Sensor System for CBRN Applications).

Within the scope of conceptual design, EU-SENSE system is made up of the following three main components: chemical detection system, situational awareness tool and training and simulation module. The system with its main parts is illustrated in Figure 1. The chemical detection system will be comprised of a network of stationary and person-worn sensors supported with novel data fusion algorithms. Fused data from the network of sensors will feed into the situational awareness tool that will give end-users the ability to simulate the hazard dispersion over the area of interest. The hazard prediction will be comprised of inverse modeling for source estimation and ensemble forward modeling to calculate potential threatened area on the basis of uncertainties from the inverse modeling. Lastly, the EU-SENSE system will consist a training and simulation module that enables end-users to train on the use of the system and rehearse specific use cases.

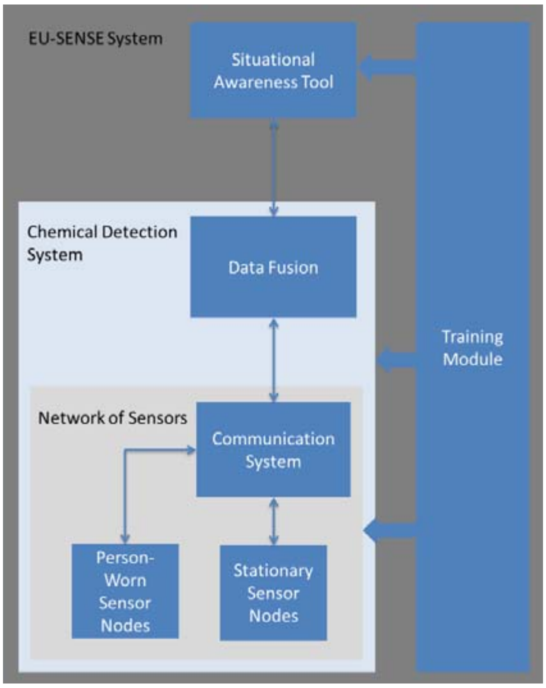

Figure 1: The EU-SENSE system and its main components

Developing the characteristics of the EU-SENSE system and its components, it is crucial to emphasize that the phase of chemical threat detection will provide novel data fusion algorithms which are going to accomplish the objective of fast and robust detection of a defined chemical agents' spectrum. Including heterogeneous sensor nodes in the network, it will give the opportunity to apply several types of sensors within a node. Furthermore, the development of the network, considering as adaptable and multi-purpose detection system, will also offer research on standardisation, which will contain definition of a unified data model prepared by the project partners. Together with network development and unified data model (especially in scope of incorporating different types of sensors with no interoperability problems), the members of the project will work on the reduction of false alarm rate. Chemical sensors are often affected by sensors reactions to environmental noise – EU-SENSE methodology aims for an automatic learning (including ability to separate between unusual, probably dangerous 'noisy' situations and normal, non-dangerous ones) and processing the environmental noise occurring in a given spatial environment, both rural and urban. Last but not least, there is the assumption that the project is dedicated to prepare sensors wear by people (end users) as well as those used in stationary way. According to this statement, it will be possible to adapt all three main components of the system to different conditions and various mission types, also to industrial incidents and mass events.

The second component – situational awareness tool – is aimed to increase situational awareness of the CBRN practitioners. Practitioners often rely on detection systems which do not guarantee an overall perspective in the area of interest. Such shortcomings cause delays in taking appropriate and timely remedies. Therefore, in response to these problems, the EU-SENSE system will include a situation recognition tool that integrates the results from the sensor network and data fusion results, and display them to CBRN practitioners on a dedicated user interface. As a result, the tool will efficiently support the decision-making process. Furthermore, EU-SENSE project will be working to develop a modelling tool that will enable end users to simulate the diffusion of threats in the area of interest.

Training and simulation module, the third part of EU-SENSE project, will provide modern and innovative tools for training crisis management units, both in the system developed under the EU-SENSE project and in general in crisis situations related to CBRN threats. The training module will contain functionalities of the operating system, with the exception of elements responsible for collecting data from actual data sources, for example sensor networks. The system will be delivered with artificial data previously prepared as training scenarios. At the same time, for the purpose of training, the functionality of preparing additional scenarios will be issued, as well as the impact of data from sensors. Such solution will allow the trainer to freely manage the training process and to train an unlimited number of scenarios with injections of various threats typical for a specific region of Europe or from specifications of end users.

2.2. REVIEW OF USER REQUIREMENTS

The EU-SENSE system is directed towards supporting users defined as end users or practitioners. Both terms relate essentially to the same extended group of people. On the one hand, they are persons directly involved in taking action at the scene of the real or potential chemical agents presence. For them, person-worn sensor nodes are dedicated. On the other hand, there are commanders (mainly from firefighters rescue teams) who are able to use stationary version of the system and supporting by it the process of making decisions, what it is extremely important in the face of any CBRN threat. Lastly, trainers could be interested in using EU-SENSE system (more precisely: training and simulation module) to train procedures for reacting, cooperating and coping with stress there it is need to deal with the chemical agents and where the EU-SENSE system is in operation. According to the scope of the interested entities, it was crucial to identified user requirements and then to check that them and scenario vignettes meet Key Performance Parameters.

2.2.1. METHODOLOGY OF COLLECTION OF USER REQUIREMENTS

A total of 42 user requirements for the EU-SENSE system were formulated as part of Task 2.1. All requirements were prioritized into "shall" and "should" requirements.

"Shall" requirements denote requirements that are mandatory whenever the criterion for conformance with the specification requires that there are no deviations. "Should" requirements denote guidelines or reco-mmendations whenever non-compliance with the specification is permissible.

In addition, all requirements were categorized as "functional" and "non-functional".

A "functional" requirement denotes any requirement which specifies what the system should do, while a "non-functional" requirement denotes any requirement which specifies how the system performs a certain function.

The user requirements were presented for the system as a whole and for the following four sub-systems: (i) chemical detection system (stationary and person-worn sensor nodes); (ii) network of sensors; (iii) situational awareness tool; (iv) training module. The questionnaire was used here to collect the requirements from the participants of the EU-SENSE Stakeholder Workshop which took place at University of Warsaw, Poland, on 8-9 August 2018. Before the workshop, the author of the questionnaire – Stig Rune Sellevåg drafted and refined requirements on the basis of the Consortium Partners feedback. Then, he distributed the questionnaire to the end users and stakeholders at Day 1 of the Workshop and discussed in plenary on Day 2. After it, the collected user requirements were sent to the Stakeholder Group on 1 October 2018 for review with possibility to give additional comments. The questionnaire was comprised of 26 questions where 17 questions addressed the chemical sensor nodes, 3 questions – the network of sensors, another 3 questions – the situational awareness tool, 2 questions – the training mode, and the last question – subjects not covered by the previous questions.

Finally, for the purpose of the system, the two user requirements were formulated (according to the point which refers to the EU-SENSE system as a whole). First said that: "The EU-SENSE system shall demonstrate improved detection performance compared to the current state-of-the-art detection technologies that are incorporated into the system for the scenarios identified in the EU-SENSE project". Second stated that: "The time needed for the EU-SENSE system to take a decision shall be equally good or improved while at the same time the false alarm rate is reduced, compared to the current state-of-the-art detection technologies that are incorporated into the system for the scenarios identified in the EU-SENSE project."(D2.2 User Requirements, 2018).

2.3. SCENARIO VIGNETTES

As it was pointed above, identified user requirements and scenario vignettes should meet Key Performance Parameters. In case of the EU-SENSE project it is impossible to describe widely the suite of adapted scenarios, because of their status classified as Consortium Confidential information. Key Performance Parameters depend on scenarios so it is crucial to introduce scenario vignettes to the paper, even if it will contain only general information. In the EU-SENSE project's proposal there were described two scenarios concerning a mass event and an industrial accident. In perspective of these kind of situation it is possible to give here only basic input for designing functionality and actions connected with validation and demonstration. Despite restricting access to full information, it may help to understand the scope of the Key Performance Parameters.

Both scenario descriptions were composed of two integral elements. One of them gives detailed information about the event. And the second, closely connected with the first one, consists a set of vignettes focusing on the most important functionalities of the EU-SENSE system.

2.4. DEFINITION OF KEY PERFORMANCE PARAMETERS

According to Deliverable D2.3, prepared by Stig Rune Sellevåg, a key performance parameter (KPP), for the purpose of the work in the EU-SENSE project, is defined as: *a performance attribute of the system that is considered critical or essential to the development of an effective EU-SENSE system that meets the user requirements for the identified suite of scenarios. The KPPs must be specific and measurable in order to support an effective test and validation of the EU-SENSE system. The KPPs are expressed in terms of a unique identification number, specification of parameters that reflect measures of performance using a minimum threshold/target goal format, which scenario vignettes and user requirements that are covered, and any caveats and comments that are of consideration for the KPP* (Sellevåg, 2018)
In the context of such definition, it was also necessary to establish framework conditions for collection of the KPPs. Finally, there were designated the following conditions:

- Each KPP shall be specific and quantifiable;
- The total set of KPPs shall cover all main components of the EU-SENSE system;
- The total set of KPPs shall cover all scenario vignettes for the suite of scenarios;
- The total set of KPPs shall cover all quantifiable user requirements prioritized as “shall” requirements;
- The total set of KPPs shall cover as many quantifiable user requirements prioritized as “should” requirements as possible.

On the basis of these framework conditions, an initial set of KPPs was formulated by the consortium partners. The final set of KPPs was established on the basis of a sequence of refinements of the initial set against the suite of scenarios and the user requirements, using appropriate tools and engagement of the members of Stakeholder Group.
Summarizing. After the theoretical part and collecting general data, in accordance with the above-mentioned definition and characteristics of conditions for collection, the following key performance parameters (KPPs) have been identified:

1. End users are trained to use the EU-SENSE system.
2. Operating time for stationary sensor nodes without maintenance.
3. Operating time for person-worn sensors in the hot zone without maintenance.
4. Time needed for physical setup of the stationary sensor nodes after being deployed to the scene of interest.
5. Time needed for making person-worn sensors ready for use.
6. Time needed for machine learning for the chemical detection system when the EU-SENSE system is used in the preparedness phase.
7. No disruption of business continuity when the EU-SENSE system is applied in the prevention or preparedness phase.
8. Instant estimation of hazardous contamination level during incidents involving chemical warfare agents or toxic industrial chemicals.
9. Estimation of source location.
10. Hazard prediction.
11. Estimation of residual, post decon, contamination level after incidents involving chemical warfare agents or toxic industrial chemicals.

Together, the 11 formulated KPPs cover all scenario vignettes and 35 out of 42 collected user requirements. (D2.3 Key Performance Parameters)

2.5. THE CONSORTIUM MEMBERS, STAKEHOLDER GROUP AND THEIR IMPACT ON THE EU-SENSE SYSTEM

The project Consortium is build up by different types organisations – with various background and status. Among members are software developers and technical specialists as well as representatives from academia and end users community. Generally, the EU-SENSE project brings together nine partners from six European countries (Great Britain, Germany, The Netherlands, Norway, Poland, Sweden). One of the category of Consortium members includes ITTI – representative of small and medium enterprises and the leader of the Consortium. Another group refers to industry sector where actively works AIRSENSE ANALYTICS – manufacturer of hazardous substance detectors. The biggest member group is created by applied researches centers: Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO), Totalförsvarets forskningsinstitut (FOI) and Forsvarets forskningsinstitutt (FFI). They are responsible for theoretical and practical expertise on dispersion modelling and situation awareness tool development. Research background has also two academic research partners: Szkola Glowna Sluzby Pozarniczej (SGSP) and University of Warsaw (UW). Both of them are public Polish universities. UW focuses on developing training system and materials, while SGSP concentrates on defining scenarios from end user perspective. Moreover, SGSP plays double role – it is the important part of academic research group as well as the end user category. In this category it is supported by Police Service of Northern Ireland (PSNI). Together they work on organizing demonstration events and validating the solution. Works of every Consortium members are divided into work packages which help to reach small goals and then milestones. A clear division of duties promotes substantive and technical work that uses the potential of all parties involved. Complicated project, which is the EU-SENSE system, requires properly planned work and skillful coordination that it is implemented from the very begging of the project.

Important role, especially in the case of identifying user requirements, plays the Stakeholder Group. As a result of engagement of the members of this Group, it was possible to designate conditions of Key Performance Parameters and then identified them. The Stakeholder Group as an advisory body outside the project management structure, consists of academia, experts, end users and industry partners who work and are interested in subjects closely related to the EU-SENSE project scope. The following members constitute the Stakeholder Group:

- Swedish Armed Forces, National CBRN Defence Centre (Sweden)
- VTT – Technical Research Centre of Finland (Finland)
- Norwegian National Unit for CBRNE Medicine (Norway)
- Imperial College London, Institute for Security Science & Technology (United Kingdom)
- CBRNE Ltd (United Kingdom)
- DJChem Chemical Poland S.A. (Poland)
- Hotzone Solutions BV (The Netherlands)
- Brandweer Zuid Limburg (The Netherlands)
- Research for Science, Art. And Technology (RFSAT) Ltd. (United Kingdom)
- Intrepid Minds Ltd (United Kingdom)
- Swedish Civil Contingencies Agency (Sweden)
- Municipal Headquarters of the State Fire Service in Siedlce (Poland)
- County Office Tarnowo Podgórne (Poland) (http://www.eu-sense.eu/stakeholder_group)

3. CONCLUSION

Chemical factors, as indicated in the first part of the paper, are now one of the elements of CBRN threats that require a lot of attention and commitment of appropriate forces and resources. The European Union, recognizing the threats and challenges in this area, supports industrial, scientific and applied researches centres so that they can work on systems supporting the efforts of practitioners. On the one hand efforts towards the issues of recognition and response in the face of chemical agents. On the other hand, towards those activities that support the training process, and that consequently allow for the substantive and practical preparation for the potential pose of a threat. Both directions are crucial from the goals point of view that the EU-SENSE project wants to achieve. The paper, briefly referring to the project, was aimed at specifying the project fully financed by the European Union. As a result of this approach, the paper presents the project which fully meets the expectations of the EU security policy. The emphasis placed on Key Performance Parameters and collection of User Requirements shows the importance that should be assigned to these elements in the process of preparing the system related to activities in the CBRN threats area. The methodology of collecting user requirements is a key process bringing members of the consortium closer to the goals, conducive to achieving further milestones and, consequently, providing a product that will meet the requirements of end users. Moreover, the Key Performance Parameters defined in the framework of the UE-SENSE project may also be used by other entities interested in determining parameters for the purposes of identifying, defining and implementing the expectations of end users in projects related to security, not only EU ones.

To conclude: it is essential to consider that the security EU projects coping with CBRN threats (on the example of the EU-SENSE project) see their goals in wider perspective than only technical and operational ones. Referring to the research questions presented in section 1.1 it should be emphasized that the main idea of developing any chemical (and other components combating CBRN threats) detection system must be supported by other, non-technical components. As a result, each implementation of, at least, a simple version of the training module is crucial here. Because of it, the EU-SENSE project aims not only to train end users how to use the system (what it is obvious), but also gives opportunity to open the system to the broader training of end users. In that perspective, end users can use the system and its training module in a tactical dimension as well as in a strategic one and wider – to help understand the methods of acting in the face of crisis threats, including those of a chemical nature.

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AN ONTOLOGY FOR THREAT MODELING AND SIMULATION OF SMALL UNMANNED AERIAL VEHICLES

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ABSTRACT
Low, Slow and Small Unmanned Aerial Vehicles (LSS UAVs) are one of the fastest-growing threats for national defense, security and privacy. A NATO task group performed a study to identify the elements necessary to define LSS models applicable for the development of necessary countermeasure to potential threats in the future. The goal of this project is to utilize this data collected by the NMSG-154 study to generate a Web Ontology Language (OWL) ontology for LSS threat modeling. The LSS ontology will form the basis for a metamodel for a domain-specific language (DSL) based on the parameters identified. This DSL will eventually be used to generate specific simulation scenarios to model potential threats caused by small drones.

Keywords: ontology, domain-specific language, UAV, LSS

1. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), or drones as they are more commonly known, have become readily available in the mainstream for personal use and hobby flying. These Low, Slow, Small (LSS) vehicles are usually programmable, which allows the user to modify behavior to include harmful intent (NATO MSG-154 2018). The rapid evolution and widespread availability of this technology has made defense against the LSS threat a real worldwide concern (Stalinsky 2017). The primary LSS threat comes from three classes of minor UAVs, which are Micro, Mini and Small. This is because these UAVs can get very close and can avoid being recognized early enough to trigger an appropriate response. The easiest way to test potential scenarios of such threats and appropriate responses in a safe environment is to use experimental frameworks (Hodicky 2016) and to follow existing standards and best practices recommended in the domains of modeling and simulation (M&S) and of autonomous systems (Hodicky 2017). This project intends to use a domain-specific language (DSL) to allow for scenario-based simulation of LSS threat models based on the categorization and discussion provided in the NMSG-154 study (NATO MSG-154 2018).

DSLs are computer languages tailored to a specific application domain. As a result, DSLs are often more expressive for that particular domain, offering ease of use. This allows domain experts, who may not be familiar with programming and general-purpose programming languages, to use a DSL to express ideas and concepts in their domain, which is commonly not possible otherwise (Bettini 2016).

In order to describe a domain-specific model, a metamodel needs to be defined first. A metamodel is, in general terms, an object-oriented model. It is composed of metaclasses, which are composed of properties. A property is either an attribute (an instance of a standard datatype) or a reference to another metaclass (Bousse, Mayerhofer, Combemale, and Baudry 2017). An indispensable part of the modeling approach is a strong semantical basis for the model which incorporates the behavioral parts of the model and their connection with the structure (Harel 2001).

A common approach for modeling requires the utilization of ontologies (Jafer, Chhaya, and Durak 2017). Ontologies describe the important ideas in the form of keywords and hierarchical relationships, which are specific to a given domain and essentially provide a vocabulary for that domain (Yao and Zhang 2009). Developing an ontology for any domain requires a detailed analysis of that domain. Ontology development is primarily a definition and categorization process (Chan 2004). Ontologies bridge the gap between people and systems, as they describe domain relationships and objects in an easily understood manner while maintaining the ability to be machine interpretable. Ontologies allow both people and computers to understand and derive new knowledge about the domain in question (Putten, Wolfe, and Dignum 2008). Therefore, ontologies can be used as a starting point for further development as a domain expands or the ontology

embraces new or additional concepts (Hilera and Fernández-Sanz 2010).
An ontology provides a quick and simplified description of a DSL, abstracting language's technical details, while highlighting key terminology and specifics. Once an ontology is built, it is a simple process to generate the language's metamodel and establish relationships among related concepts. Generating this ontology is the first task in this project.

2. NMSG-154 STUDY

This work uses the NMSG-154 study as a basis for categorization of important terms and parameters related to LSS threat modeling. The MSG-154 derived its activity from dedicated NATO Industrial Advisory Group (NIAG) Studies to Counter LSS (NATO NIAG Study SG-170 2013; NATO NIAG Study SG-188 2015; NATO NIAG Study SG-200 2017), where specific technologies for detection and neutralization were identified. The NMSG-154 study performed a categorization of UAVs based on the physical characteristics and other capabilities of individual drones (Proietti, Goldiez, Farlik, and Di Marco 2017), which is essential to developing measures to counter threats from the specific UAVs. The aim of the study was to take into account the variety of the commercially available LSS aerial platforms in order to define LSS models from different points of view (Proietti, Goldiez, Farlik, and Di Marco 2017).

2.1. NSMG-154 Tasks

The study identified several parameters that can be used to model LSS UAVs. The work was broken down into several work packages. The first task was the categorization of LSS to summarize the different characteristics and parameters that build upon existing classification systems.
The next task was the physical modeling to model behavior during flight, including the flight profile, navigation algorithms, flight duration and impact physics among other flight characteristics. Detectability, intelligence and tactics modeling were included to create a full picture of an LSS flight, the threats posed by it and to determine the best response to counter any such threat. The first task of categorization was completed and summarized by Proietti et al. (2017) and their summary has been used as the basis for this work.

2.2. Model Definition Categories

The main categories identified for model definition were (Proietti, Goldiez, Farlik, and Di Marco 2017):

- typology, which defined certain model parameters such as the modes in which the drone can operate;
- the material used to manufacture the drone;
- flight parameters and performances;
- the kind of propeller used;
- reference to NATO Classification;
- the type of navigation system used;
- the remote controller characteristics (if any/available);
- the payload, considering both own sensors and possible hazards.

These model categories each have several parameters identified within the study. These parameters form the starting point of the ontology for small UAV threat modeling. A sample of parameters has been shown in Table 1. It is important to note that this study provided a non-exhaustive list of parameters that can be used to model LSS threats. The parameter list can be expanded in accordance with the technical development of drones as well as with the level of fidelity required in modeling.

Table 1: Selected Parameters for LSS Categorization (Proietti, Goldiez, Farlik, and Di Marco 2017)

Category	Parameter
Typology	Fix Wing
	Rotary Wing
	Flapping Wing
Dimension	Length
	Wingspan (fix wing)
	Height
	Weight

3. ONTOLOGY DEVELOPMENT

The ontology was developed by first categorizing the parameters and separating them into a hierarchical collection of terms with definitions. The relationships between these terms was then determined in order to obtain a collection of related terms for LSS UAV modeling. These parameters have originally been described by the NSMG study (NATO MSG-154 2018) but have been formalized for use in simulation and as part of a UAV body of knowledge in this work. This ontology was published in the OWL format for direct conversion into a metamodel for a DSL.
The important terms in the ontology are discussed here.

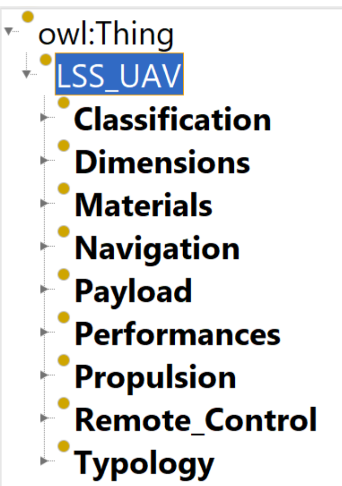

Figure 1: High-Level View of LSS UAV Ontology

The primary categorization yields the classes shown in Figure 1. Each category has multiple subcategories which have a definition for the metamodel. The subcategories are shown in this section.
Classification refers to NATO classes for UAVs and can be seen in Figure 2. This classification occurs on the basis of the weight of the UAV as well as its purpose (Fahlstrom & Gleason 2012).

Figure 2: Terms in Classification Category

All dimensions needed to accurately model the shape, size and aerodynamics of the UAV are recorded in the Dimensions category as shown in Figure 3.

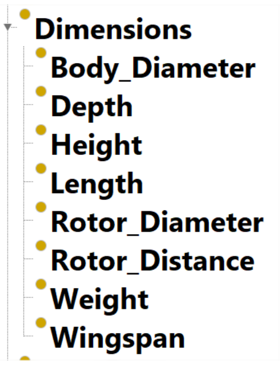

Figure 3: Terms in Dimensions Category

The material the UAV is made out of defines the characteristics of the UAV and imposes limits on its performance. Thus, it is an important parameter in the modeling of the vehicle. The category consists of the type of material being used and the properties of the material, as can be seen in Figure 4.

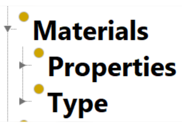

Figure 4: Terms in Materials Category

The material properties are off several types such as its color, temperature, luminosity and thermal emissivity, to name a few. A full list of the parameters considered for modeling is shown in Figure 5.

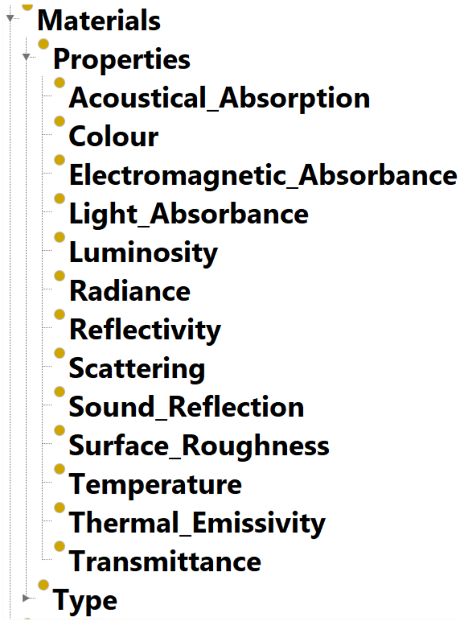

Figure 5: Properties included in Subcategory of Materials

In addition to the properties, the type of material is recorded too, so the properties can be automatically populated. The types are first subdivided into the following categories: composites, metals, polymers and other materials. This subcategory listing is shown in Figure 6.

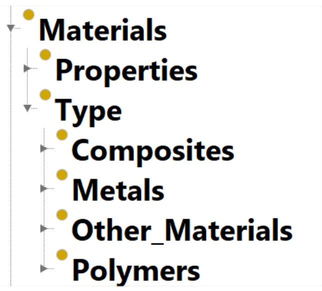

Figure 6: High-Level Types of Materials

The specific type of materials the UAV is made out of are covered under the subcategories. This includes the materials that UAVs are currently made from, and also lists other materials they could be made out of in the future to allow for accurate modeling. These types of materials can be seen in Figure 7.

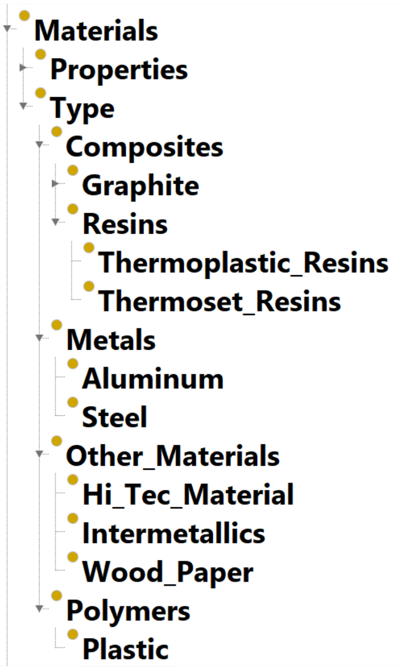

Figure 7: All Possible Types of Materials

The type of navigation capabilities of the UAV dictates the maneuvering and performance, and needs to be accounted for in the modeling of the systems. The more redundancy in the systems, the more accurate it usually is (NATO MSG-154 2018). The type of systems present in the UAV can be seen in Figure 8.

Figure 8: Terms in Navigation Systems Category

Each UAV carries some equipment and sensors onboard. This is categorized as the payload and is considered to be of two types in the modeling process. One is the set of sensors that convey flight data and could possibly be jammed or manipulated. The other type is some sort of offensive mechanism to engage any forces. The hazardous material could be of various types and the danger posed by each type can be simulated based on the type of hazard load. Those types being considered during modeling have been shown in Figure 9.

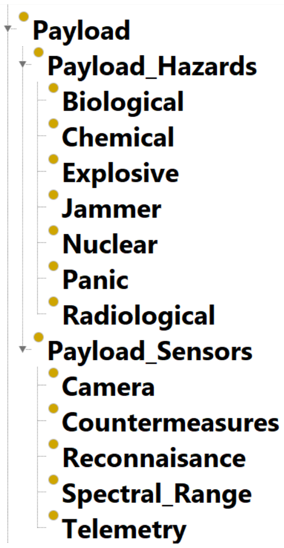

Figure 9: Terms related to Payload

The performance parameters of the LSS are used to model its flight characteristics and behavior. The keywords for this category can be seen in Figure 10.

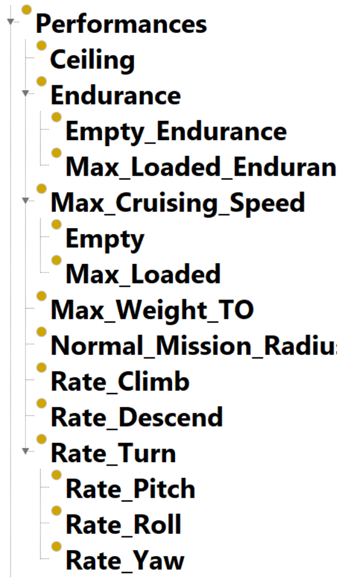

Figure 10: Performance Parameters of LSS

The propulsion characteristics are discussed in the form of engines, propellers, battery and solar capabilities of the vehicle. These terms can be seen in Figure 11.

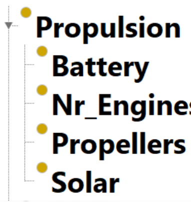

Figure 11: Propulsion Parameters of LSS

Since the vehicle is unmanned, a thorough simulation requires the modeling of the remote-control parameters. These can be seen in Figure 12.

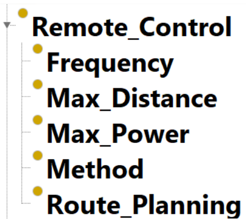

Figure 12: Remote Control Properties

The UAV type can be defined simply by a few type names. These are shown in Figure 13. Several physical properties and shapes of the UAV are determined by the type name listed.

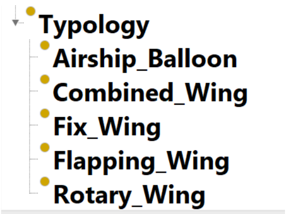

Figure 13: Terms in Typology Category

4. METAMODEL DEVELOPMENT

The metamodel was developed using Ecore in Eclipse Modeling Framework (EMF). The Ecore format is basically a subset of UML Class diagrams. This Ecore model of the class definition is the metamodel, which describes the structure of the model and provides a template for the generation of individual models (Jafer, Chhaya, Durak, and Gerlach 2018). The metamodel includes all data items and the relationships between them. A metamodel is then further utilized to construct a model, which is a concrete instance of this structured data.

The metamodel generated based on the ontology has been broken up into two halves so that the text can be read. It has not been expanded fully as it consists of the same elements as present in the ontology. This metamodel is shown in Figure 14 and Figure 15.

The first half of the metamodel can be seen in Figure 14. The LSS UAV is the parent entity and has all the properties described in the rest of the metamodel. As per the ontology, it has a *Typology* class which is a category type, enumerated by the elements in the ontology under that category. The dimensions of the UAV are described in the *Dimensions* class. The *Materials* class has a materials type enumeration, which contains the names of the materials shown in Figure 7 and also a class of material *Properties*. The *Performance* data of the UAV is recorded in a separate class.

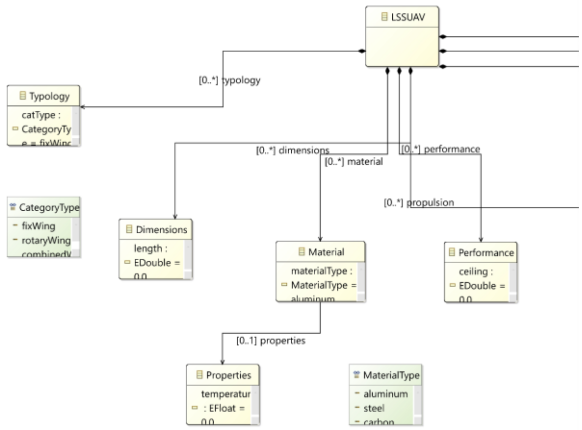

Figure 14: Metamodel Details, part (a)

The second half of the metamodel can be seen in Figure 15. This includes the *Navigation* properties of the UAV as well as the *RemoteControl* capabilities. The payload is also described in this section as per the parameters identified in the ontology. The NATO *Classification* is also covered in the form of an enumeration.

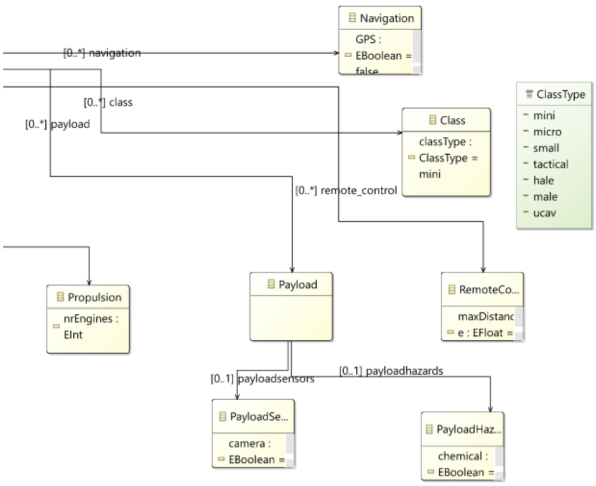

Figure 15: Metamodel Details, part (b)

This metamodel uses the parameters identified by the MSG-154 (NATO MSG-154 2018) to describe the properties of a UAV. Once the LSS vehicle can be modeled, it can be used in a simulation to assess the threat posed by it on any type of environment.

5. CONCLUSION AND FUTURE WORK

This paper discusses the results of the categorization task of the NMSG-154 task group. The work here expands upon the data found during the task and used the results to develop an ontology for modeling LSS threats which affect safety and security. The ontology developed was used to generate a metamodel for a DSL.

The DSL can describe a UAV and its properties and parameters. A specific model of a UAV generated using this metamodel can then be used in a simulation to understand its behavior in various situations. Being able

to model the physical properties of a UAV is the first step towards simulating its behavior. Using the data presented in by the NMSG-14 task group, a more formalized metamodel was generated, which can actually be used for such modeling and scenario generation, and ultimately for simulation of the threats posed by these vehicles.
The next task is to use the DSL for scenario generation of LSS threats. Executing specific scenarios in a simulation can enable us to understand the risks posed by the UAV and to prepare a plan to counter the threat appropriately.

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SOFT TARGET ASSESSMENT SOFTWARE

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ABSTRACT

The soft targets and crowded places are closely related to the risk of attack to the group of people. These places are very specific because the moving in the soft targets is not organized. That's mean these places have open and public access. The attack in the soft targets (attack on the soft targets) can have a significant impact on the population and life of the people. The main aim of the proposed software is to analyze the features of the object. According to the analyses, we can define the corrective action, which can have a significant impact on the security situation in the object.

Keywords: soft targets, assessment, software, methodology

1. INTRODUCTION

The definition of soft targets can have some differences in the Czech Republic and abroad. We can see some differences in the next part of the paper.

Soft Targets and Crowded Places (ST-CPs) are locations that are easily accessible to large numbers of people and that have limited security or protective measures in place making them vulnerable to attack. ST-CPs can include, but are not limited to, schools, sports venues, transportation systems or hubs, shopping venues, bars and restaurants, hotels, places of worship, tourist attractions, theaters, and civic spaces. ST-CPs do not have to be buildings and can include open spaces such as parks and pedestrian malls. ST-CPs will not necessarily be crowded at all times – crowd densities may vary between day and night, by season, and may be temporary, as in the case of sporting events, festivals, or other special events. (U.S. Department of Homeland Security 2018)

Attacks against soft targets have a powerful effect on the psyche of the populace. Modern terrorist groups and actors had redrawn the battlefield lines, and places where civilians once felt secure have been pulled into the war zone. (Ministry of the Interior Czech Republic 2016)

Soft targets are places with a large concentration of the people and the low level of security measures against the violent attacks. (Hesterman 2015)

We used our definition to this research: *"The soft targets are objects (buildings, areas, open spaces) in which a large number of the visitors are located. These objects don't have integrated the special security and safety measures which can:*

- *defend the violent attack on the lives of the visitors,*
- *positively increase the reactions to the incident,*
- *protect the lives of the visitors.*

The violent attack can cause the death or injury of the person or the more persons who are in the object or in the closed area of the objects."

In this paper, we describe the methodology of the assessment of the soft targets software tool. In section 1, we describe the introduction to this paper. In section 2, we analysed the last attacks on the civilians in 2018. Section 3 describes the methodology of the software. The case study (shopping centres and schools) is described in section 4. Finally, we summarize the conclusion in the last section 5.

2. THE ATTACKS ON THE CIVILIANS IN THE SOFT TARGETS

The attacks on soft targets are very popular in the last years. The reason for the attacks on the soft targets is that the soft targets are full of unprotected civilians and these places are called "free gun zones". (Hesterman 2015)

In Figure 1, you can see the timeline of the attacks in the 2018.

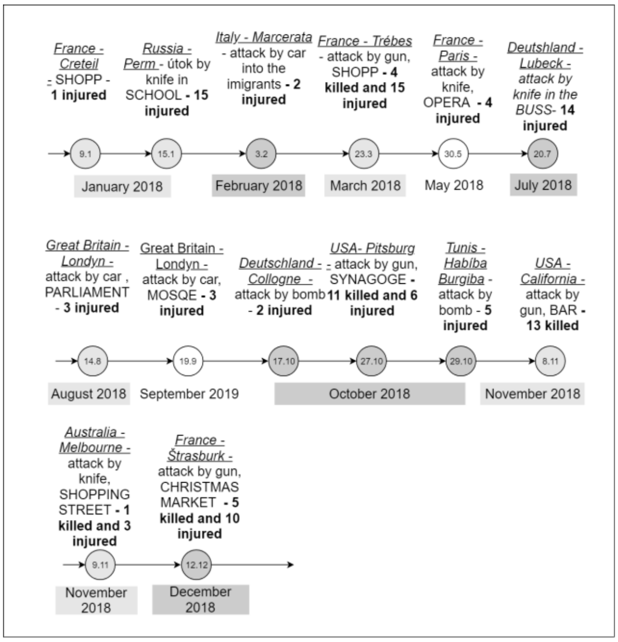

Figure 1: The analysis of the last attacks in 2018.

In Figure 1, we can see the number of killed civilians. The situation in Figure 1 describes the places which can be attacked. According to the (Hesterman 2015), can be described the similar motivations and goals that cross all brands of the terrorist and criminal group to attack the soft targets:

- Easier, cheaper, and short planning cycle. (The attack the soft targets is easier, cheaper and short that the attack to the military objects. The effect on the population has significand impact)
- Increased likelihood of success.
- Credibility. (Status in the group.)
- Recruiting value.
- Flexing muscle.
- Compensating for weakness.
- As a last gasp.
- Backed into the corner.
- Test a new strategy, tactic, or weapon.
- Fund-raising.
- Quickly damage a market.
- Delegitimize a government.
- Cause political instability.
- Make a country look weak internationally.
- To attain global media coverage.
- A target-rich environment.
- Psychological fear.
- Make a domestic issue international.

[2]

In 2019 (21.4.2019) exposes 6 bombs in Sri Lance. This attack can be called as the biggest attack in 2019 (up to now). This attack caused 42 deaths and 280 injured civilians.

In this part of the paper was described the attacks on the soft targets. We can constant that this part of the research still needs to innovate and develop the next approaches to solving the situation.

3. THE METHODOLOGY OF THE SOFTWARE

The software logic is based on the analyses of the features of the objects according to the questions and answers. Each of the answers has defined the level of security. According to the threats, we can define the weight of the criteria and weight of the answer. The software can help us with the comparison of the objects, with the definition the corrective actions and simulations too. In Figure 2, we can see the process of the methodology of the proposed software tool. This process is the basic main process according to them we can analyze the soft targets and situation in soft targets.

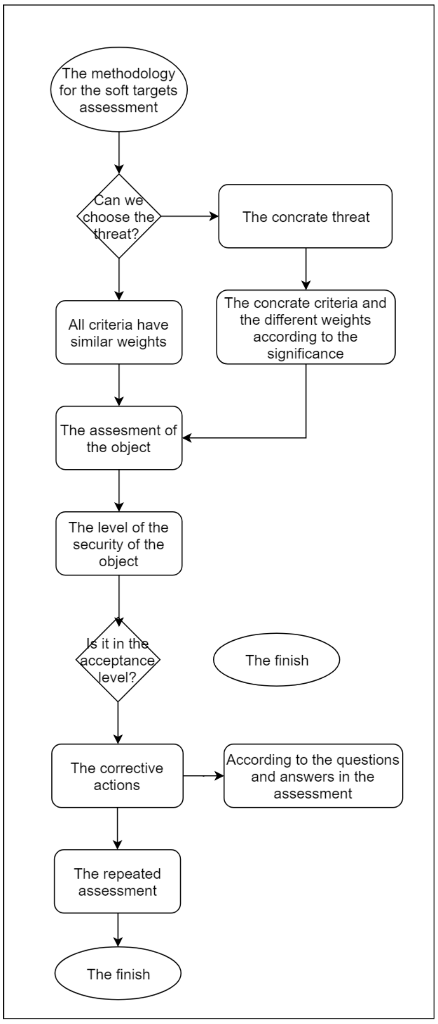

Figure 2: The process of the proposed methodology.

The process in Figure 2 is static. We need to analyze the objects in the dynamic part of the software. The state of the object (situations in the building or on the event) can be changed in time. We need to monitor the situation in these objects. The dynamic part of the proposed software can change the situation in the object according to the changes in the closed area and closed locations.

3.1. The definition of the locality security coefficients

The locality is identified by the closed places and threatens of these places. The next parameter which can have a significant impact on the security of the locality is the city. The population in the city is a very important factor. The population in the city can be changed in time (planning the vent in the city).

In figure 3 we can see the locality coefficients in Prague (the capital city the Czech Republic). The value 1 represents the most unsafety situation. We can see that the value 1 represents the airport for example.

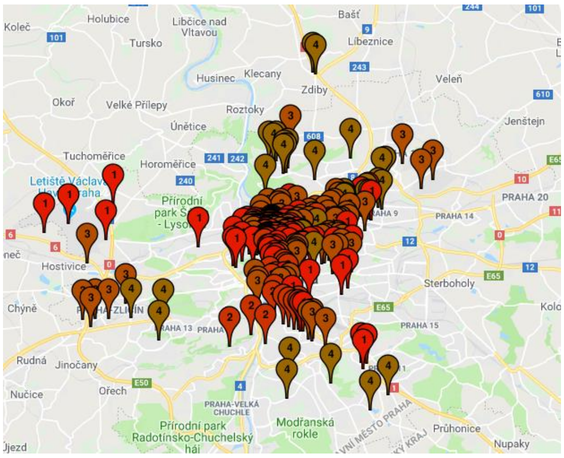

Figure 3: The example of the locality coefficints.

As we can see in figure the situation in the capital city is better when we evaluated the closed places. The center of the city has defined the most unsafety situations because the probability of the attacks and the number of visitors is higher than out of the city center.

4. THE CASE STUDY

This part of the paper is oriented to the case study of the proposed methodology for the assessment of the soft targets. The first part of this case study analyses the shopping centers. The second part of the case study is oriented to the results of the analysis of the school's objects. The best security situation is defined by the numerical value of 10. On the other hand, the value 0 or 1 represents the worst security situation in the object. We didn't use to the specific analyses (no with the definition of the threat).

4.1. The shopping centers case study

The objects in this case study have similar localization. All of these objects are in the Czech Republic. The locality (city) of these objects is similar to the criminality index.

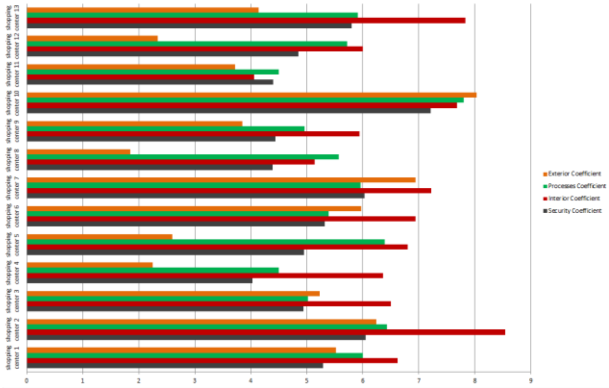

Figure 4: The case study – shopping centers.

As we can see in Figure 4, we analyzed 13 objects (shopping centers). The data from the graph are in table 1.

Table 1: The data of the case study – shopping centers.

	shopping center 1	shopping center 2	shopping center 3	shopping center 4	shopping center 5	shopping center 6
Exterior Coefficient	5,52	6,24	5,23	2,25	2,6	5,97
Processes Coefficient	6	6,43	5,02	4,5	6,39	5,39
Interior Coefficient	6,62	8,54	6,5	6,36	6,8	6,94
Security Coefficient	5,29	6,05	4,94	4,03	4,95	5,32

	shopping center 7	shopping center 8	shopping center 9	shopping center 10	shopping center 11	shopping center 12	shopping center 13
Exterior Coefficient	6,94	1,85	3,85	8,03	3,72	2,34	4,14
Processes Coefficient	5,96	5,57	4,96	7,8	4,5	5,72	5,91
Interior Coefficient	7,22	5,14	5,94	7,68	4,06	6	7,83
Security Coefficient	6,03	4,39	4,44	7,21	4,4	4,85	5,8

As you can see in Figure 4 and table 1, the shopping center 10 has calculated the best security situation. On the other hand, the worst security situation is in the shopping center 4. The shopping center 10 has calculated the whole security coefficient of 7.21. The shopping center 4 has calculated the whole security coefficient of 4.03.

The city of these two objects is the same. The localization of these two objects is different. The object 4 is in the middle of the center. The closed area of the shopping center 4 is more unsafe as the shopping center 10. The object 4 is in the same areal with the Rock concert hall and the gas station. On the other hand, object 10 has a bigger area. The object 10 has more than 1 enter/ exit. The object 1 has only 1 enter/ exit. The entrance to the parking in the object 4 is managed by the barriers. On the other hand, the object 10 doesn't have managed enter/exit to the parking. These objects have only open parking. The arithmetic average of this group of the case study (shopping centers) is 5.21.

4.2. The school objects case study

This case study analysis the primary schools. These objects are important because the primary users of these objects are children. All of these objects are in the same region.

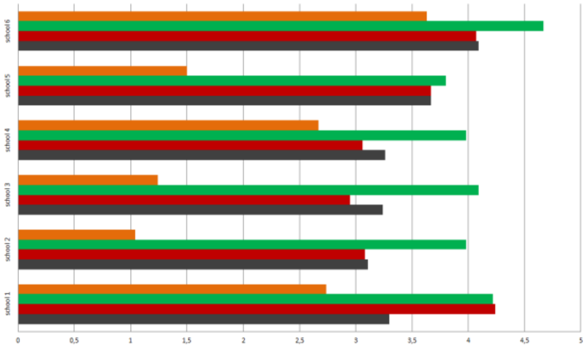

Figure 5: The case study – schools.

We analyzed 6 schools as we can see in Figure 5. The data from the graph are in table 2.

Table 2: The data of the case study – schools.

	school 1	school 2	school 3	school 4	school 5	school 6
Exterior Coefficient	2,74	1,04	1,24	2,67	1,5	3,63
Processes Coefficient	4,22	3,98	4,09	3,98	3,8	4,67
Interior Coefficient	4,24	3,08	2,95	3,06	3,67	4,07
Security Coefficient	3,3	3,11	3,24	3,26	3,67	4,09

The schools 6 has the best security situation. On the other hand, school 2 has the worst security situation. The object 6 has value 4.09 and object 2 has the value of the security coefficient 3.11. The object 6 has two enters and exits. The object 6 has a more secure closed area than object 2. Object 2 has only 1 enter and exit. The arithmetic average of this group of the case study is 3.45.

Finally, we can compare these two groups of objects. The shopping centers have more users than in primary schools. The risk of these objects can be higher. On the other hand in the category (schools) are popular users (children). The level of security measures is higher in shopping centers. The shopping centers have installed the security devices (cameras) and the security workers are presented in the object during the whole open hours. The number of users is different. The primary schools are visited by the children, but the number of children is under 100 children. On the other hand, the shopping centers are visited by all types of people for the whole day. The number of visitors is under 1000 persons per day.

5. CONCLUSION

According to the previous part of the paper, we can constant the security coefficients answer to reality. The schools have not integrated so secure and safe measures then the shopping centers. The schools are non-profit organizations that don't have so the financial resources to the security devices as the shopping centers. According to the statistics data (HESTERMAN, 2016), the more attacks are in the schools. This statistic is done mostly in the USA. This statistic considers to the statistic criminal acts (no only terrorist attacks).

According to the results of the statistic, we can constant, that this part of the verification of the proposed methodology was successful. We can say that the results answer to reality. In the next part of the research, we need to develop the dynamical part of the proposed software. The dynamical part of the software will simulate the progress of the security coefficients in the object. According to the simulations we can see which objects are threatened by the planning event in the closed area.

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MODELING REALISTIC 3D TREES USING MATERIALS FROM FIELD SURVEY FOR TERRAIN ANALYSIS OF TACTICAL TRAINING CENTER

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ABSTRACT
This paper elaborates processes of modeling 3D trees for the simulation of the Army's Tactical Training Center. The ultimate objective is to develop the 3D model database for inclusion to a game engine library. The adopted methodology includes collecting a forestry inventory for later 3D tree modeling in a Unity's 3D Tree Modeler. Leaves and trunks were closely modeled using the data collected from the real site in the package SpeedTree modeler. Three tree types were sampled to demonstrate how close and realistic the adopted processes were to produce result 3D models for inclusion to the simulation of the tactical center. Visual comparison was made to show the final models. 3D scenes generated from the inclusion of the models were illustrated in comparison to the photo taken from the site. Further studies to adopt surface modeling data from UAV terrain mapping for tree canopies were recommended to verify photorealism of the processed 3D models.

Keywords: 3D tree model, forest inventory, tactical training

1. INTRODUCTION

This paper forms part of the report of the project 3D Simulation of the Army's Tactical Training Center of the Royal Thai Army. The most important objective of the project is to develop the 3D model of the training center in support of decisive and judgmental military trainings. The terrain of the 2 x 0.5 km2 study area is sparsely vegetated and needs 3D tree modeling to construct the realistic 3D model for such purpose of terrain analysis. The Army embraced the proposed 3D modeling of the study area for terrain analysis as part of OCOKA (Observation and Fields of Fire, Cover and Concealment, Obstacles (man-made and natural), Key or Decisive Terrain, Avenues of Approach. This current work is extended from that of Robert et al (2018) who attributed the realism of the modelled and visualized virtual world mainly to the detailed field survey together with UAV and GIS data modelling. The modelled terrain and geo-database were incorporated into military planning processes for tactical planning.

Kumsap et al (2005) addressed a rough survey of approaches to the generation of vegetation models. Continuous developments were witnessed and found in Sun et al (2009), Pratihast (2010), Pirk et al (2012), Xie et al (2015) and Wang et al (2018). Models grown by L-Systems and models from commercial libraries are dominant with growth parameters being determined and interpolated to create convincing animations. Wang et al (2018) proposed an algorithm for generating novel 3D tree model variations from existing ones via geometric and structural blending. Thus, the proposed framework only considered the tree branches and ignored the tree leaves in order to ensure the smooth change of foliage structures along blending paths. However, the methodology in this current work adopted SpeedTree® Modeler's combination of a home-grown procedural algorithm and hand drawing, which is more artistic an approach and fitted with the heterogeneously vegetated nature of the study area. This paper addresses the manipulation of data collection for a forestry inventory by modeling sampled trees in a Unity's SpeedTree® Modeler rather than attempting to investigate an algorithm to append photos of tree's leaves and barks to the 3D tree model. Furthermore, the validation of modeled outcomes that is deemed significant to complete the simulation process is left for further study and publication.

2. FOREST INVENTORY

In this section, the details of field survey and quantitative forest characteristics of tactical training field are explained as seen in section 2.1 and 2.2, respectively.

2.1. Field survey

Forest inventory has been carried out in environmental and ecological monitoring and management (Fischer, C., Kleinn, C., Fehrmann, L., Fuchs, H., and Panferov, O., 2011; Metsaranta, J. M., Shaw, C.H., Kurz, W. A., Boisvenue, C., and Morken, S., 2017). Studies describe investigations of forestry inventory in biomass carbon estimation (Brown, S. and Gaston, G., 1995; Mateos, E., Garrido, F., and Ormaetxea, L., 2016; Athanassiadis, D., and Nordfjell, T., 2017; Young B.D., Yarie J., Verbyla D., Huettmann F., Stuart Chapin F., 2018). To make it spatial related, geo-referencing of forest inventory data must be included. As such, we performed forest inventory by modeling in a geographic information system (GIS) prior to transferred into 3D tree modeling in a Unity's 3D Tree Modeler.

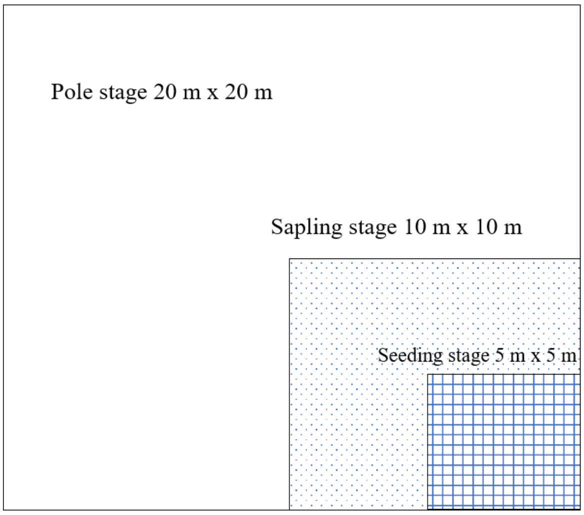

Figure 1: A platform of sample plot

Table 1: Example of tree characteristics retrieved from pole stage sample plot

Species	GBH[a]	Ht[b]	X[c]	Y[c]	X_1[d]	X_2[d]	Y_1[d]	Y_2[d]
Diospyros ebenum	0.41	7.67	20351	82698	2.50	2.33	2.83	1.83
Diospyros mollis	0.39	6.75	20349	82701	1.75	2.13	1.63	1.50
Leucaena leucocephala	0.38	7.17	20355	82700	2.67	2.00	1.17	2.33

[a]Girth at breast height 1.30 meter > 0.30 meter, [b]Tree height in meter, [c]X and [c]Y coordinate referenced in military grid system (47P QS), [d]Tree canopy

In this research, field survey using sample plots was implemented to acquire forest inventory. Our study area is one of military training fields of the Royal Thai Army Training Command, covering 2.0 kilometer x 0.5 kilometer. Six sample plots of 20 meter x 20 meter were carried out. Extrapolation was also included using Unmanned Aerial Vehicle (UAV) mapping so as to fulfil additional spatial information needed (Tomppo, E., Olsson, H., Ståhl, G., Nilsson, M., Hagner, O., and Katila, M., 2008; Haywood, A., Mellor, A., and Stone, C., 2016). Figure 1 displays a platform of sample plot. There are three sections in each platform, which are 20 meter x 20 meter, 10 meter x 10 meter and 5 meter x 5 meter. These different sections are designed to acquire characteristics of tree stages including pole, sapling and seeding stage, respectively. The characteristics of trees in pole and sapling stage retrieved from one platform are shown in Table 1 and 2. The vegetation species discovered in pole and sapling stage were geo-located in military gird referencing (MGR) format. Considerably, we sampled merely species and counts of seeding trees.

Table 2: Example of tree characteristics retrieved from sapling stage sample plot

Species	Count	Ht[a]	X[b]	Y[b]
Diospyros ebenum	1	2.0	20359	82690
Diospyros ebenum	1	2.5	20345	82701
Afzelia xylocarpa	1	4.0	20347	82699

[a]Girth at breast height 1.30 meter < 0.30 meter, [b]X and Y coordinate referenced in military grid system (47P QS)

The plant information received from sample plots were further used to investigate quantitative forest characteristics of tactical training field. The forest characteristics were quantitated by number of sample plots found, frequency percentage, counts, and frequency class in order to study forest homogeneity of this tactical training field. The results of quantitative forest characteristics are explained in section 2.2.

2.2. Quantitative forest characteristics of tactical training field

Table 3 illustrates quantitative forest characteristics of tactical training field. Trees in pole and sapling stage were sorted in descending order. The percentage of tree frequency was used to describe forest homogeneity, which was categorized into five classes (From class A to class E). The frequency percentage of Class A to Class B is 1-20, 21-40, 41-60, 61-80, and 81-100, respectively. Forest homogeneity is referred as to $\frac{Class\ E+Class\ D}{Class\ B+Class\ C}$. It shows strong homogeneity when homogeneity value is more than one. As illustrated in Table 3, this tactical training field is homogenous with homogeneity value 1.5.

Table 3: Quantitative forest characteristics of tactical training field

Order	Species	Number of sample plots found	Frequency (%)	Count[a]	Class[b]
1	*Diospyros ebenum*	5	83.3	15	E
2	*Holarrhena pubescens Wall. ex G.Don*	5	83.3	4	E
3	*Millettia kangensis*	5	83.3	7	E
4	*Diospyros mollis*	5	83.3	12	E
5	*Lagerstroemia calyculata Kurz*	4	50.0	3	D
6	*Spondias pinnata (L. f.) Kurz*	4	50.0	6	D
7	*Bridelia ovata Decne*	3	50.0	3	C
8	*Hopea ferrea*	3	50.0	3	C
9	*Leucaena leucocepphala (Lam.) de Wit*	3	50.0	4	C
10	*Combretum quadrangulare Kurz*	3	50.0	3	C

[a]Number of trees found, [b]homogeneity class

In can be concluded that those trees in pole and sapling stage as seen in table 3 represent majority of tree species found in the tactical training field. The forest inventory collected from the field survey was later transferred into 3D tree modeling in a Unity's 3D Tree, elaborated in next section.

3. 3D TREE MODELING FOR UNITY'S SPEEDTREE® MODELER

The conceptual methodology is threefold as illustrated in figure 2. First is the implementation of forest inventory in order to prepare geo-database of vegetation characteristics. Second is the modeling 3D Trees in Unity's SpeedTree® Modeler using actual materials of barks and leaves. Thirdly, it is the approach of visualization of 3D Tree Models based on different levels of details prior to include in Unity game engine library. The elaboration of this conceptual methodology is explained below.

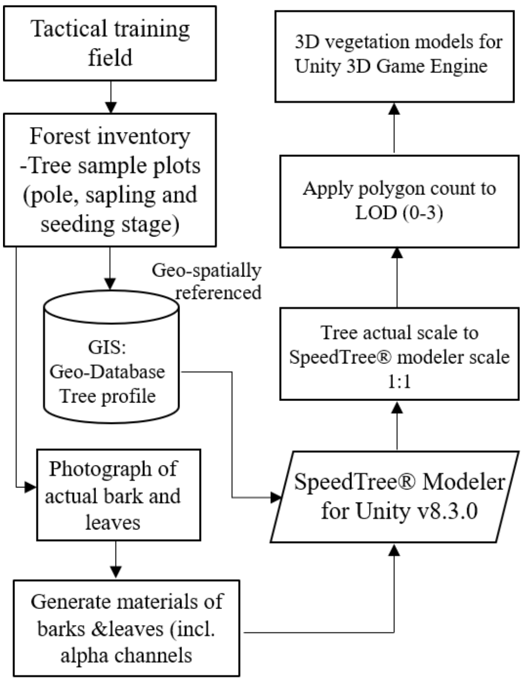

Figure 2: A process of modeling 3D trees in SpeedTree® Modeler

3.1. Modeling 3D Trees in Unity's SpeedTree® Modeler

With the final goal to develop the 3D model database for inclusion to the Unity game engine library, the process of modeling 3D trees in SpeedTree® Modeler was developed as shown in Figure 2. The training field of 2 x 0.5 square kilometer in which the research team performed tree sample plotting for the forest inventory selected and outlined by the Royal Thai Army Tactical Training Center. Fine resolution imagery from UAV was used to obtain geo-referenced tree footprints while field survey photos were source of site-specific barks and leaves. These materials from the site along with the tree profiling data of the geo-database were input to the SpeedTree® Modeler and scaled to replicate actual height as indicated by tree profiles. For example, *Diospyros ebenum* was 7.67-meter-high (see table 1). The height of this tree was modeled from actual scale to SpeedTree® modeler scale as seen in Figure 3 (Left image).

Prior to export 3D trees from SpeedTree® Modeler to Unity 3D game engine, levels of details (LOD) were taken into consideration. Polygon count limits spatial resolution displayed in game engine. Since our study was aimed to develop tactical training field in troop level, we limited polygon count of LOD at 10,000. The number of LOD 0-LOD 3 polygons were pre-computed to avoid lengthy rendering time during 3D scene computation with appropriate level of detail in relation to viewing distance (Kumsap et al, 2005). Four LOD for three 3D tree models (see Figure 3-5) were then added to the library. Figure 3 displays *Diospyros ebenum* in LOD 0, and Figure 4-5 shows LOD 2 of *Diospyros mollis* and *Leucaena leucocephala,* respectively.

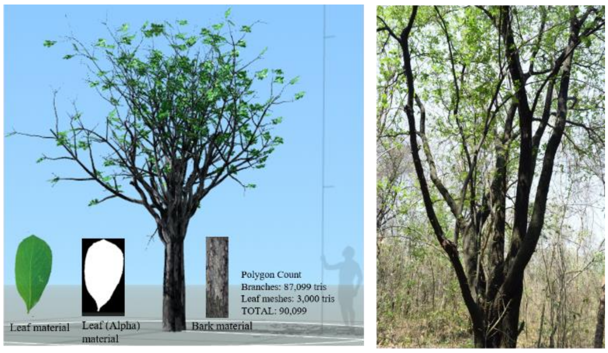

Figure 3: A visual comparison between a computer-generated image (left) and real photo (right) of *Diospyros ebenum* (Ebony)

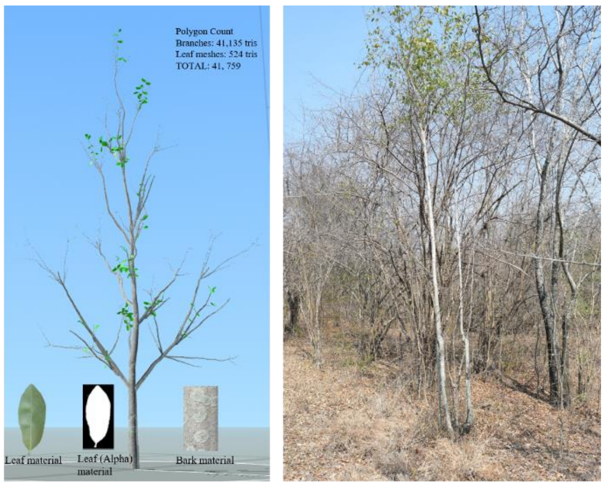

Figure 4: A visual comparison between a computer-generated image (left) and real photo (right) of *Diospyros mollis* (Ebony tree)

The nature is literally impossible to model and simulate using a scientifically and technologically complete and flawless manner. An individual tree is modeled with the addition of photographical materials from the field to enhance the sense of geo-specific simulation to provide an accumulative geo-typical simulation product. The accumulation of individually modeled object contributes to tactical training in a way that trainees stay connected to the actual site of training. Therefore, the modeler outcomes will be further validated in an accumulative approach, which was planned to study the visual comparison of the tree profile from the actual site and the terrain modeling and visualization from the result 3D tree models. This emerging notion deserves effort, resource and time to further investigate, thus beyond the scope of this actual material tree modeling methodology.

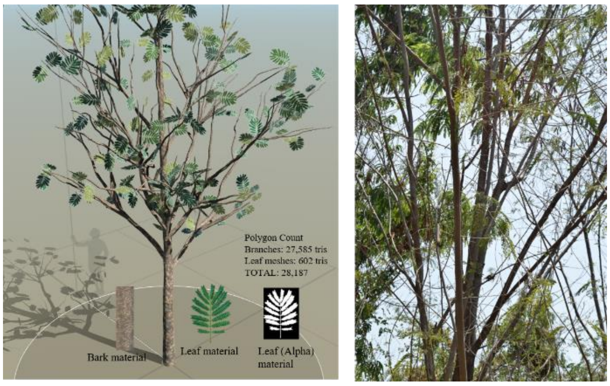

Figure 5: A visual comparison between a computer-generated image (left) and real photo (right) of *Leucaena leucocephala* (White popinac)

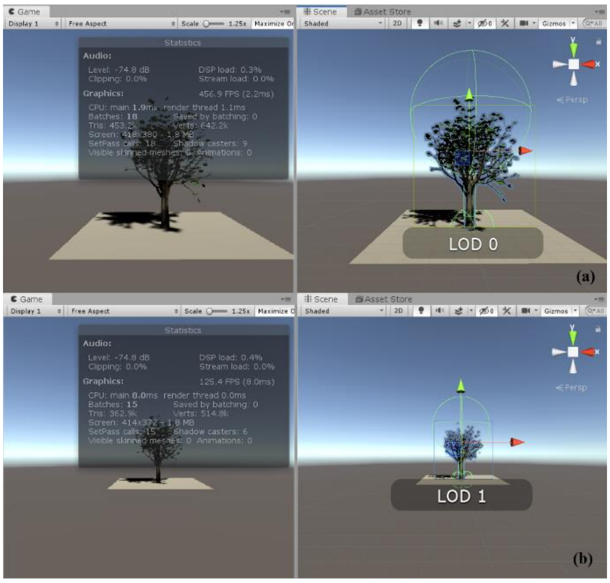

Figure 6: *Diospyros ebenum* tree plotted in Unity 3D game engine (a) in LOD 0 and (b) in LOD 1

3.2. Visualization of 3D Tree Models

The result of 3D tree modeling was illustrated in Figure 3 – 5 with photos taken from the site displayed alongside. The foliage density of the model was manually edited to reflect that of the real tree. Mesh materials from the site were added to branches and trunk to obtain quite a resembling 3D model from visualization. Modeling the foliage density and length demanded lengthier time than expected, thus excluded from this report and could have resulted in close resemblance with the actual trees. However, adding more detail of leaves, branches and trunk to the model could lead to a lengthier rendering time and unnecessary extra details being rendered without being actually viewed (Kumsap et al, 2005). Therefore, the LOD 0 – LOD 3 were generated for inclusion to the database of Unity game engine for proper rendering and visualization purpose.

Figure 6 showcases statistics of rendering *Diospyros ebenum* tree models at LOD 0 and LOD 1. The number of polygons to construct LOD 0 at 453.2k of polygons and LOD1 with 362.9k polygons. The LOD in SpeedTree® Modeler is dynamic for smooth changes as the distance to the tree changes, hiding any geometry unnecessary to render.

3.3. Vegetated Terrain Modeling for Terrain Analysis

To construct 3D scene shown in Figure 7, the geo-database and tree profile were incorporated to produce a rather photorealistic view of the study area. Tree footprints collected in Section 2.1 yielded tree density and heterogeneity, main factors to converge visualization and first-hand experience of terrain viewers. The first-person view was well welcome for the terrain analysis of the Royal Thai Army's Tactical Training Center. However, statistical results of the acceptance of the proposed methodology were out of the scope of this study and recommended for further investigation.

Figure 7: 3D trees plotted on Terrain of the study area.

4. CONCLUSION AND FUTURE WORK

Our work was aimed to transfer modelled 3D trees into Unity 3D game engine to further develop a virtual world tactical training simulator for infantry company commander and infantry platoon leader which is not existing in the Royal Thai Army. In virtual world military training, plants characteristics affect the perspective and ability of trainees. Key terrain analysis must be included in intelligence preparation of the battlefield called OCOKA. Vegetation characteristics are necessary to be observed in individual virtual training; for example, an avenue of tank movement, height, diameter, and canopy of trees must be considered. The realism of trees and terrain enhance the success of intelligence preparation of the battlefield. The proposed modeling approach enhances the realism of the modelled and visualized virtual world tactical training system, which the performance of trainees would be improved. Thus, we denied using ready-made trees. The adopted methodology manipulated the data collection for the forestry inventory and attempted to model the sampled trees in the Unity's SpeedTree® Modeler rather than to investigate a modeling algorithm for 3D tree modeling. The forest inventory was modeled in a GIS prior to transferring into 3D tree modeling in the Unity's 3D Tree Modeler. The barks and leaves of each vegetation species were photographed during field survey and used as mesh for actual materials of barks and leaves. The alpha channel was enabled for leaf material generation, thus allowing opacity among leaf space. Since the study was aimed for the tactical training field at troop level, the LOD polygon count was limited to 10,000. In addition, the number of LOD0-LOD3 polygons were pre-computed to accelerate the 3D scene computation, and the rendering of each LOD was illustrated to reveal gradual changes of modeling details. The visual comparison was illustrated for the visualization of mesh materials added to the branches and trunk at sufficient resemblance to the actual trees. However, the complete rendering of the 2 x 0.5 km^2 study as well as the result of incorporating 3D scene computation results with OCOKA terrain analysis are in current investigation and worthy of further discussions. UAV terrain modeling can be a reliable and quick source for collecting tree canopies and highly recommended to verify photorealism of the processed 3D models. In addition, the modeler outcomes needed further validation, which was planned to study the visual comparison of the tree profile from the actual site and the terrain modeling and visualization from the result 3D tree models.

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AGENT-BASED SIMULATION OF A FIRE DEPARTMENT'S RESPONSE TO EMERGENCY INCIDENTS: AN UPDATED MODEL

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ABSTRACT
A modelling and simulation (M&S) approach was earlier developed, following statistical analysis of the emergency incident database of the Vaughan Fire & Rescue Service covering eight years of consecutive incident records from January 2009 to December 2016. The M&S framework, which could potentially be replicated for fire departments across Canada, involved two different simulation models running on separate platforms: (i) an *Incident Generation Engine*, which simulates the 'arrival' of emergency incidents, and (ii) a *Response Simulation Model*. The current report covers only an update of the Response Simulation Model, an agent-based model developed using AnyLogic. Two issues associated with the earlier Response Simulation Model have specifically been addressed and resolved by the updated model. We report on findings from our simulation experiments based on the updated model.

Keywords: Fire department, fire response, emergency response, discrete event simulation, agent-based simulation, Vaughan Fire & Rescue Service

1. INTRODUCTION
Solis *et al.* (2018a, 2018b) reported on modelling and simulation (M&S) of a fire department's responses to emergency incidents. The M&S project involved two simulation models running on separate platforms:

1. *Incident Generation Engine* – a discrete-event simulation model developed using CPNTools 4.0 (CPNTools 2017), generating the incidents used as inputs for the second model; and
2. *Response Simulation Model* – an agent-based model developed using AnyLogic.

1.1. Vaughan Fire & Rescue Service
The above models were created following statistical analysis of emergency incident and responding unit data of the Vaughan Fire & Rescue Service (VFRS) covering eight years of consecutive incident records from January 2009 through December 2016, and based upon VFRS operating policies and procedures. The City of Vaughan is the 17th largest city in Canada with a population currently estimated to be just over 330,000 (Canada Population 2019). It is located north of Toronto, the capital of the province of Ontario and the largest Canadian city with more than 3,000,000 inhabitants.

The research team had initially been commissioned to conduct, on behalf of the Canadian Association of Fire Chiefs (CAFC), research aimed at developing a simulation engine leveraging the National Fire Information Database (NFID) of Canada (Solis *et al.* 2018a). The NFID, which was first made available to the researchers in April 2017 and updated in July 2017, covered 11 years (2005-2015) of fire incident records across Canada. However, serious data gaps were found in the NFID by Solis *et al.* (2018a). Moreover, the NFID involves only fires and fire-related incidents, which generally do not account for the majority of emergency incidents that fire departments across Canada respond to. For example, in the case of the cities of Toronto and Vaughan in 2016, only 28.1% and 25% of all incidents responded to by Toronto Fire Services and VFRS, respectively, were fire and fire-related incidents (Solis *et al.* 2018b).

The NFID was, therefore, deemed to preclude a meaningful modelling and simulation of a fire department's responses to emergency incidents. It was in this context that the research team approached the VFRS Senior Command Team in order to seek advice and explore an appropriate way for moving forward with the M&S effort. The VFRS – recognizing an opportunity to gain potential strategic, tactical, and operating insights – offered to quickly make available its 2009-2016 emergency incident and responding unit dataset.

1.2. VFRS Emergency Incidents: 2009-2016

VFRS' yearly numbers of emergency responses over the 8-year period from 2009 to 2016 are presented in Figure 1.

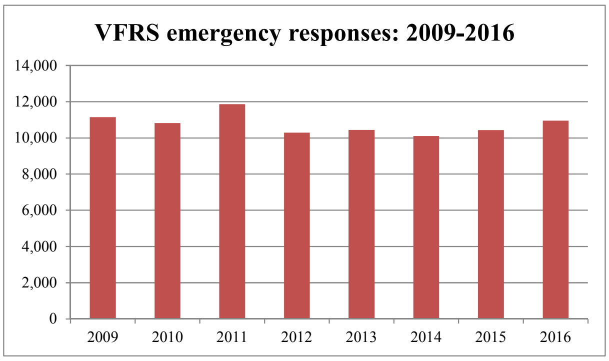

Figure 1: VFRS Emergency Responses per Year in 2009-2016
(Sources: Vaughan Fire & Rescue Service 2009-2016.)

According to census data (Table 1), Vaughan's population grew from 238,866 in 2006 to 306,233 in 2016, representing a growth rate of 2.5% per annum over the 10-year period. The numbers of emergency incidents do *not* appear to exhibit a corresponding rate of growth, apparently as a result of fire safety education and prevention initiatives of the VFRS.

Table 1: Population of the City of Vaughan

Census Year	Population
2006	238,866
2011	288,301
2016	306,233

(Source: City Population 2019.)

The annual breakdowns of emergency incidents in 2009-2016 according to major categories are summarized in Table 2. Fires and fire-related incidents (including false alarms) have accounted for between 25% and 36% of all VFRS emergency responses during the 8-year period from 2009 to 2016. Medical emergencies, on the other hand, have been between 34% and 42% each year during the same period. According to its latest annual report, VFRS responded to a total of 11,834 emergency incidents throughout the year 2018 (Vaughan Fire & Rescue Service 2018), of which 47% were medical emergencies.
In the 2009-2016 dataset, however, a more specific incident type is assigned to each incident in an 'Incident Code' field. There have been 83 such incident codes in use, which form part of the data inputs into the Incident Generation Engine. Each incident generated by this first model includes the incident code as one of the key incident features.

1.3. Incident Generation Engine

The first simulation model, the Incident Generation Engine, was implemented as a discrete event simulation with CPNTools 4.0 as the platform. This model produces a list of emergency incident occurrences, each with an incident ID and the following five key incident features (Solis *et al.* 2018a, 2018b):

1. incident 'arrival' time,
2. incident code (indicating type of incident),
3. incident location (Latitude and Longitude GIS coordinates, based upon a discrete partitioning of the entire geographical region covered by VFRS, using a lattice granularity of 500 m × 500 m),
4. APPTOT (or Alarm Processing Plus TurnOut Time, corresponding to Roll-out Time stamp minus Alarm Receipt Time stamp), and
5. on scene time (for the first responding unit at the scene of the incident).

Table 2: Breakdowns of VFRS Emergency Incidents: Years 2009 to 2016

Year	**2009**	**2010**	**2011**	**2012**
No. of incidents	11,147	10,814	11,864	10,286
Property fires/explosions	7%	8%	8%	7%
False alarm/non-fire calls	25%	28%	25%	23%
Rescues	11%	15%	16%	15%
Public hazards	4%	4%	3%	4%
Medical	42%	34%	36%	38%
Other responses	11%	11%	12%	13%
Total (%)	100%	100%	100%	100%
Year	**2013**	**2014**	**2015**	**2016**
No. of incidents	10,447	10,099	10,428	10,950
Property fires/explosions	6%	8%	7%	9%
False alarm/non-fire calls	24%	23%	24%	16%
Rescues	16%	17%	17%	18%
Public hazards	4%	5%	5%	4%
Medical	36%	38%	36%	41%
Other responses	14%	9%	11%	12%
Total (%)	100%	100%	100%	100%

(Sources: Vaughan Fire & Rescue Service 2009-2016.)

The chronological list of incidents output by the Incident Generation Engine is the set of inputs that are simulated in the Response Simulation Model. The Incident Generation Engine has already been presented and described in detail by Solis *et al.* (2018a, 2018b), and is accordingly only summarized here.

2. UPDATED RESPONSE SIMULATION MODEL

The current report covers only an updated version of the Response Simulation Model that was developed earlier (Solis *et al.* 2018a, 2018b).
While the Incident Generation Engine is a discrete event simulation model, we used agent-based modelling (ABM) to develop the Response Simulation Model, using the AnyLogic simulation platform. The agents in the model consist of the entities as summarized in Table 3.

Table 3: Agents in the Response Simulation Model

Agent	Description
Dispatcher	Representing the VFRS communications centre, which receives an emergency call and alerts the appropriate fire station or stations to respond to the incident
Emergency Point	Representing the location of an emergency incident, which changes its status based on the actions of other agents
Station	An agent that receives the call from the Dispatcher, and changes its status according to availability of resources (vehicles/crews)
Vehicle	An entity (responding unit) that receives the dispatch order from the Station, and uses the GIS subsystem within AnyLogic to determine and use the appropriate street route

Two issues associated with the earlier model have specifically been addressed and resolved by the updated model:

- an inaccurate representation of VFRS' fire districts and stations, and
- a model simplification that allows only either one or two responding units being dispatched to an emergency incident.

2.1. VFRS Fire Districts and Stations

The proper representation of VFRS' fire districts, with their corresponding geographical areas, and the locations of their respective fire stations (shown in Figure 2) are now incorporated as a shapefile in the updated Response Simulation Model.
The nine fire stations and current numbers of responding units are presented in Table 4. The actual number of vehicles located at each station is greater than the reported number of responding units, the latter being dependent upon the number of firefighting crews assigned to the station. Each responding vehicle is assigned a four-person firefighting crew. The addition of one responding unit at a station, therefore, requires one additional 24-hour firefighting crew, which corresponds to an incremental labour cost for VFRS of around CAD 2.5 million per year.

2.2. VFRS Incident Response Protocol

Current VFRS operating protocol calls for 1, 2, or 4 responding units depending upon the type of incident (entered as 'incident code'). Out of a list of 83 incident codes, the protocol requires four vehicles to respond to each of 15 codes, as summarized in Table 5. On the other hand, 24 incident codes require only one responding unit, while another 44 incident codes call for two responding units. The incident code assigned by the Incident Generation Engine to an incident accordingly determines the number of responding units (1, 2, or 4) that the Dispatcher agent "sends" to the scene of that incident.

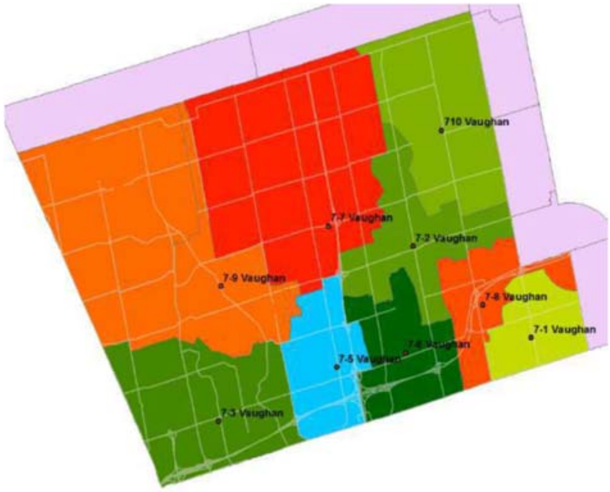

Figure 2: VFRS' Nine Fire Districts and Fire Station Locations

Table 4: VFRS Current Number of Responding Units per Station

District/Station	No. of Responding Units
71	2
72	2
73	2
75	2
76	1
77	1
78	1
79	1
710	1

Table 5: Incident Codes Calling for Four Responding Units per Current VFRS Response Protocol

Incident Code	Incident Description	No. of Trucks (Protocol)
1	Fire	4
2	Combustion Explosion (including during fire)	4
11	Overpressure Rupture (no fire - e.g., steam boilers)	4
12	Munition Explosion - (no fire - e.g., bombs, dynamite)	4
13	Overpressure Rupture - gas pipe (no fire)	4
21	Overheat (no fire - e.g., engines, mechanical device)	4
22	Pot on Stove (no fire)	4
24	Other Cooking/toasting/smoke/steam (no fire)	4
25	Lightning (no fire)	4
26	Fireworks (no fire)	4
29	Other pre fire conditions (no fire)	4
51	Bomb, Explosive Removal, Standby	4
63	Building Collapse	4
601	Trench rescue (non fire)	4
602	Confined space rescue (non fire)	4

In developing the initial Response Simulation Model, the research team recognized the fairly complicated, and apparently tedious, treatment within the AnyLogic model of dispatching four responding units coming from 2, 3, or 4 different fire stations that may have available vehicles/crews.
Based on the initial statistical analysis, it was determined that only 5.3% of the total number of incidents in the 8-year dataset would have required dispatching four responding units per response protocol, as seen in Table 6. However, when considering total number of responding units, such incidents would have, in fact, required 14.2% of all vehicles needing to be dispatched. Given this fairly significant proportion, it was believed appropriate for the research team to redouble its efforts in incorporating into the Response Simulation Model within AnyLogic the dispatching of four responding units whenever any of the 15 incident codes listed in Table 5 arises.

Table 6: Expected Distribution of Number of Responding Units per Response Protocol: 2009-2016

No. of Responding Units Required per Protocol	No. of Incidents	% of Total No. of Incidents	Total No. of Responding Units Required per Protocol	% of Total Responding Units
1	50,108	60.5%	50,108	40.3%
2	28,264	34.1%	56,528	45.5%
4	4,426	5.3%	17,704	14.2%
Total	82,798	100.0%	124,340	100.0%

However, the actual number of responding units dispatched to an incident may vary from the number specified per protocol, depending upon various factors – in particular, the actual situation as reported by the first responding unit arriving at the scene of the incident. We looked into the numbers of responding units, as reported in the 2009-2016 Incident Responding Units file, and derived the actual distribution shown in Table 7. We see that, in fact, only 71.4% of all responding units were either the lone unit or one of only two units responding to an incident. In the earlier version of the Response Simulation Model, of course, 100% of all simulated responding units would have fallen into either of the two categories (lone unit or one of two units).

Table 7: Distribution of Actual Number of Responding Units: 2009-2016

Actual # of Vehicles Dispatched per Incident	No. of Incidents	% of Total No. of Incidents	Total No. of Responding Units	% of Total Responding Units
1	57,494	69.4%	57,494	45.0%
2	16,819	20.3%	33,638	26.4%
3	2,864	3.5%	8,592	6.7%
4	1,712	2.1%	6,848	5.4%
More than 4	3,909	4.7%	21,055	16.5%
Grand Total	82,798	100.0%	127,627	100.0%

3. NEW SIMULATION RESULTS

With the model having been updated, we conducted, and collected statistics from, 365 replications of the experiment, with each replication simulating one day of VFRS responses to emergency incidents (corresponding to a one-year period from January 1 to December 31). The *Incident Generation Engine* was used to produce 365 days of incidents, and the resulting incident list was used as input for the *Response Simulation Model*.
Table 8 summarizes the number of emergency incidents throughout a simulated year, by district, and the corresponding number of responding units required. It may be worth noting that the average number of responding units per incident is highest, at 1.76, in the case of District 76, which is predominantly an industrial district.

Table 8: Simulated Number of Emergency Incidents and Required Responding Units

District	No. of emergency incidents	No. of responding units required	Average no. of responding units per incident
71	1,692	2,501	1.48
72	1,586	2,290	1.44
73	1,648	2,435	1.48
75	1,201	1,888	1.57
76	635	1,120	1.76
77	1,900	2,719	1.43
78	850	1,283	1.51
79	1,061	1,586	1.49
710	690	994	1.44
Overall	11,263	16,816	1.49

One of the interesting statistics arising from the simulation is the utilization of responding units at each fire station. For instance, Station 77 is currently allocated one responding unit. In our 365-day simulation experiment, this station has no available responding unit 12% of the time (see Figure 3).

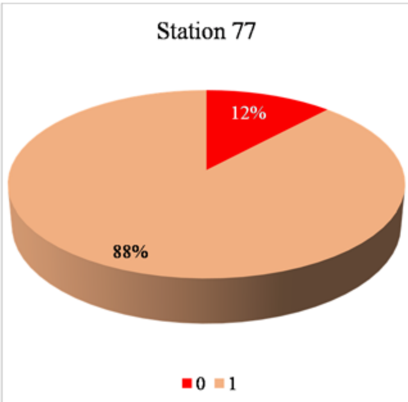

Figure 3: VFRS Station 77 – Simulated Responding Unit Utilization/Availability

Table 9 shows that, of the 1,900 incidents occurring in District 77 in the simulated year, just over 62% of the

2,719 required responding units are provided by its own station, Station 77, while close to 38% are units coming from other stations. Stations 72, 79, and 75 respond to around 19%, 8%, and 7%, respectively, of incidents in District 77. This would appear to make sense, particularly given the close geographical proximity of these three stations to District 77 as seen in Figure 2.

Table 9: Simulated Responses by Various Fire Stations to Incidents in District 77

Responding Station	Responses to District 77 Incidents	% to Total
71	0	0.0%
72	515	18.9%
73	3	0.1%
75	182	6.7%
76	21	0.8%
77	1,695	62.3%
78	1	0.0%
79	220	8.1%
710	82	3.0%
Total	2,719	100.0%

Station 75, on the other hand, with two responding units, does not have an available vehicle and crew only 5% of the time, while having two available responding units 89% of the time (see Figure 4).

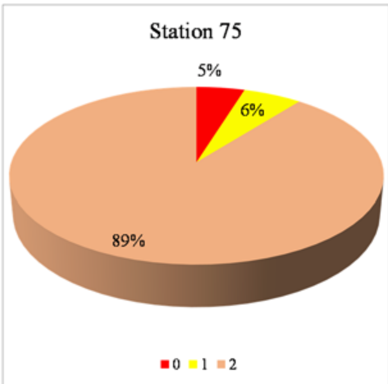

Figure 4: VFRS Station 75 – Simulated Responding Unit Utilization/Availability

As expected, when distances traveled to incident locations are much longer, we find that average response times are very significantly greater when fire stations respond to incidents outside their own district than when the incidents are within the district (Table 10). It is, therefore, desirable to see a fire station being able to respond as much as possible to its own district's incidents. We accordingly considered looking further into the situation where Station 77 responds to only 62% (refer back to Table 9) of the emergency incidents within District 77.

We considered two modifications to the current assignment of responding units (as summarized in Table 4), giving rise to the following three Scenarios:

Scenario 1. Current number of responding units at each fire station (Table 4).

Scenario 2. A second responding unit added to Station 77 (all other responding unit assignments remain the same).

Scenario 3. Move one responding unit from Station 75 to Station 77 (all other responding unit assignments remain the same).

Table 10: Average Response Times per Fire Station

Station	Responses within own District	Responses outside own District	Responses Overall
71	00:05:40	00:11:03	00:06:27
72	00:07:21	00:11:24	00:07:59
73	00:08:13	00:14:40	00:08:40
75	00:07:22	00:11:47	00:08:24
76	00:07:30	00:12:41	00:08:31
77	00:07:33	00:12:42	00:08:27
78	00:08:16	00:10:54	00:08:38
79	00:07:24	00:12:33	00:08:23
710	00:07:45	00:13:32	00:08:18

Table 11 provides a summary of responding unit assignments to the nine VFRS fire stations corresponding to each of these three scenarios. It must be noted that Scenario 2 would require a 14th responding unit for VFRS and entail a significant incremental operating cost.

Table 11: Number of Responding Units per Station Under Scenarios 1-3

District/Station	Scenario 1	Scenario 2	Scenario 3
71	2	2	2
72	2	2	2
73	2	2	2
75	2	2	1
76	1	1	1
77	1	2	2
78	1	1	1
79	1	1	1
710	1	1	1
Total No. of Responding Units	13	14	13

Figures 5, 6, and 7 show (for Scenarios 1, 2, and 3, respectively) the simulated responses by individual fire stations to incidents occurring within their own districts. Based upon the numbers reported in Figures 5-7, Table 12 shows the percentages, under each scenario, of the responding units required by incidents occurring in each district that are responded to by the district's own fire station. This table, therefore, allows a comparison of the percentages resulting under the alternative Scenarios 2 and 3 with the percentages under Scenario 1. With Stations 76, 77, 78, 79, and 710 each having only one responding unit currently assigned (under Scenario 1), Districts 76, 77, 78, 79, and 710 all have much lower percentages of own station's response (between 53%

and 66%) in comparison with Districts 71, 72, 73, and 75 (between 86% and 88%) which each have two responding units.

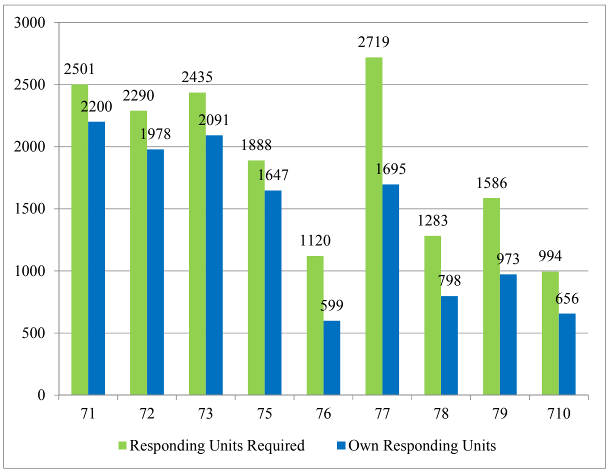

Figure 5: Responding Units Under Scenario 1

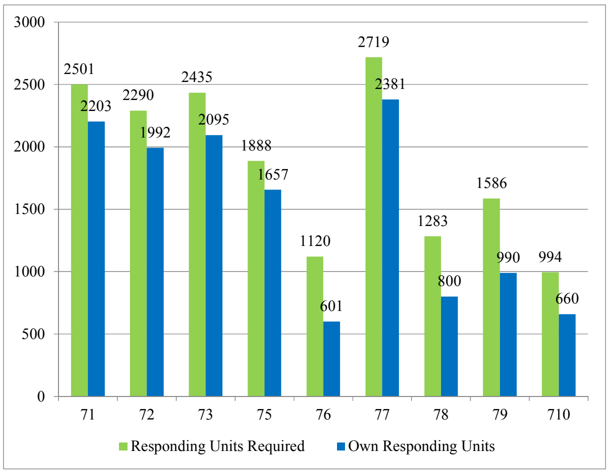

Figure 6: Responding Units Under Scenario 2

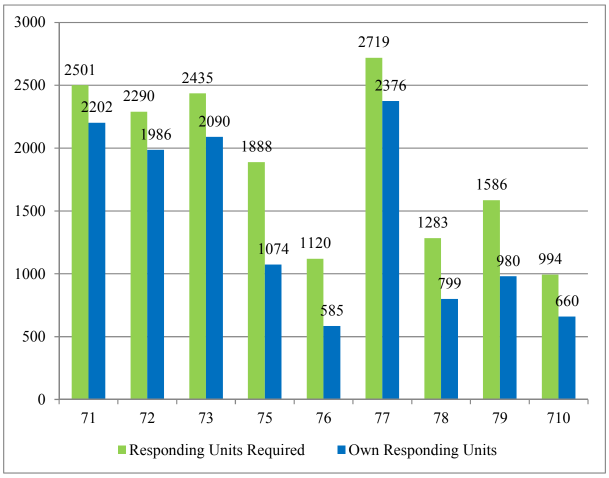

Figure 7: Responding Units Under Scenario 3

Understandably, under Scenario 3 where one responding unit is reassigned from Station 75 to Station 77, the percentage of own station's response to incidents decreases from 87% to only 57% of 1,888 in the case of District 75, while increasing from 62% to 87% of 2,719 in the case of District 77. On the other hand, under Scenario 2 where an additional responding unit is assigned to Station 77, the percentage of own station's response increases from 62% to close to 88% in the case of District 77, while the other districts' percentages either remain the same or marginally improve by up to one percentage point. Overall, Scenario 3 gives rise to only a 0.7 percentage point increase in own stations' responses to incidents, while Scenario 2 yields a heftier 4.4 percentage point improvement.

Table 12: Percentages of Required Responding Units Provided by Own Station Under Scenarios 1-3

District	Responding units required by incidents in the district	%-age of required responding units provided by own station		
		Scenario 1	Scenario 2	Scenario 3
71	2,501	88.0%	88.1%	88.0%
72	2,290	86.4%	87.0%	86.7%
73	2,435	85.9%	86.0%	85.8%
75	1,888	87.2%	87.8%	56.9%
76	1,120	53.5%	53.7%	52.2%
77	2,719	62.3%	87.6%	87.4%
78	1,283	62.2%	62.4%	62.3%
79	1,586	61.3%	62.4%	61.8%
710	994	66.0%	66.4%	66.4%
Overall	16,816	75.1%	79.6%	75.8%

Consistent with the comparisons of percentages in Table 12, we see that Table 13 shows average response times improving by 14 seconds overall under Scenario 2. In fact, under Scenario 2, the average response times improve by between 11 and 16 seconds in every district (except for District 71 with only a one second improvement). We do see an improvement in overall response times under Scenario 3, but only by 3 seconds. However, the effects on average response times in individual districts are inconsistent, with some districts showing improvements while other districts show increases in average response times.

Table 13: Comparison of Average Response Times Under Scenarios 1-3

District	Scenario 1	Scenario 2	Scenario 3
71	00:06:27	00:06:26	00:06:27
72	00:07:59	00:07:48	00:07:41
73	00:08:40	00:08:28	00:09:03
75	00:08:24	00:08:10	00:09:06
76	00:08:31	00:08:19	00:08:30
77	00:08:27	00:08:14	00:08:18
78	00:08:38	00:08:22	00:09:06
79	00:08:23	00:08:09	00:10:06
710	00:08:18	00:08:03	00:09:19
Overall	00:08:30	00:08:16	00:08:27

We see, therefore, that the impact of adding another responding unit (under Scenario 2) to Station 77, which currently is assigned only one responding unit, is significantly greater than just transferring one responding unit to Station 77 from Station 75 (under Scenario 3).

4. CONCLUSION AND FURTHER WORK

4.1. Conclusion

This study shows that using the proposed M&S approach combining discrete event and agent-based simulation models makes it possible to investigate in detail the dynamics and impacts of various resource allocation and reallocation scenarios on key performance indicators (KPIs) of a fire department.
Combining the results with cost-benefit analyses will provide decision makers with tools that they need to enhance a fire department's decisions regarding adding and equipping new or existing fire stations in their operational areas.

4.2. Further Work

Investigation of other alternative scenarios associated with assignment/reassignment of responding units (vehicles/crews) to existing fire stations is ongoing. Further work may also include looking into effects on KPIs of either new or relocated VFRS fire stations.
As indicated by the district/station numbers, a District/Station 74 had previously been in existence. The researchers plan to investigate the effects on KPIs of a proposed reintroduction in the near future of District/Station 74. The analysis will, of course, take into consideration District 74 boundaries in relation to other districts, as well as the location of Station 74 and any possible reassignment of responding units.

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REACTIVITY TO CRISIS SITUATIONS IN THE TRANSPORT SECTOR

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ABSTRACT
The article deals with the response to crisis situations in road transport. Crisis situations are recorded in every critical infrastructure sector. Road transport is no exception. The material transported annually records the growth. The planning of the transport does not take into account the risk of the planned route or the categorization of the transport unit. When categorizing the transport unit the limited choice of suitable routes. The article is focused on real-time responsiveness to crisis situations. The purpose is to minimize next risks that could result in more and more serious events when one crisis situation arises.

Keywords: Critical infrastructure, traffic, Transportation, Transport Management, Risk Management, Incident Modeling, Accident Modeling.

1. INTRODUCTION

International transport is as important as domestic transport across Europe. Shipping material is important to ensure the functioning and proper functioning of the state. Critical infrastructure elements are protected. Each country ensures its correct functionality and safety. Every element of critical infrastructure is important to every state and a response is important in the event of an emergency. Minimizing the consequences and timely response can prevent this event from spreading to a larger part of the territory.

Critical infrastructure elements are important to all. Each country has different priorities for each infrastructure element. Some elements of critical infrastructure also interact in a crisis. The crisis can turn into a critical event and cripple the whole country. A country can become paralyzed to neighboring states or other countries that have a link with a paralyzed country.

The normal transport process is set up where we want to transport the shipping unit and deliver it. Currently, this information is insufficient. The transport unit category should be taken into account when scheduling shipments. Risk shipping units are moving around us. These transports threaten the lives and health of the population, as well as critical infrastructure elements. Traffic management should create a safe environment where people move. It is also necessary to avoid further crisis situations, whereby these decisions increase the risk of their occurrence. Minimizing risk will increase security and ensure state functionality.
The case study is divided into two parts. The first part focuses on the possibilities of the tool in the planning phase. The second part focuses on the response to events during the real-time transport process. The proposed instrument describes a real-time response to crisis situations. Prevention management during the transport process minimizes risks and consequences. In response to ongoing crisis situations, customer requirements can be met with the proposed tool. During the transportation process, the route is rescheduled and diverted to an alternative route. This diversion should ensure a safer route without much delay.

2. CRITICAL INFRASTRUCTURE

Critical infrastructure is handled according to Act No. 240/2000 Coll. on crisis management. Critical infrastructure is composed of elements that are important for everybody. Each element must meet certain requirements to be identified as a critical infrastructure element.
Critical infrastructure elements are assessed on the basis of cross-cutting criteria. After meeting the cross-sectional criteria, they are classified into individual sectors, which are currently outlined. These branches will be discussed in the next subchapter.

2.1 Critical infrastructure element

The elements of critical infrastructure are mainly construction, equipment and means of public structure. Critical infrastructure elements are determined according to sectoral, cross-cutting criteria. These criteria are described in Government Order No. 432 / 2010sb.
Critical infrastructure sectoral criteria are divided into nine sectors. Every sector is important for every country.

- Energy,
- Water management,
- Food and Agriculture,
- Healthcare,
- Traffic,
- Communication and IT systems,

- Financial market and currency,
- Emergency services,
- Public administration.

The sectors are interconnected via links. These links show which elements are dependent on each other from a certain perspective. Thus, any crisis in one sector can affect other critical infrastructure sectors as well. This phenomenon may result in the influence or creation of a crisis in sectors with which this sector has no direct link. for example, transport and energy have a direct link to traffic and public administration Based on these events, we divide links into:

- Direct binding.
- Indirect coupling

Any direct link is important not to interfere with the proper functioning of other sectors of critical infrastructure elements. Cross-border connections are more important in crisis prevention and management. Elements that are indirectly linked to the paralyzed sector can also be protected if timely reactions occur and minimized consequences.

3. STATISTICAL DATA

Table 1 shows the statistics of the transport sector. The transport sector is divided into four sub-categories. These categories include:

- Road transport.
- Rail transport.
- Air transport.
- Water transport.

Categories are popular among residents. The data in the table shows the popularity of each subcategory. This data shows the number of transported units in each transport sector. Water transport is also one of the transport sectors. This sector is used for the transport of materials, but not for the transport of persons as a result of watercourses on which people could be transported.

Table 1 Amount of transported material in the Czech Republic.

Thinks (in thousand)	2015	2016	2017
Road transport	438 906	431 889	459 433
Rail transport	97 280	98 034	96 516
Air transport	5 790	5 632	6 362
Water transport	1 853	1 779	1 568

Table 1 shows the dominance of road transport in popularity.

Popularity is represented by the amount that is transported each year in each transport sector. A large amount of material transport increases the number of risks due to the increasing number of means of transporting the material. Increasing the number of risks reduces the security of the state as a result of a crisis or emergency situation. Other sectors tend to stagnate. The popularity of road transport is becoming increasingly popular every year. This phenomenon can be seen in Figure 1.

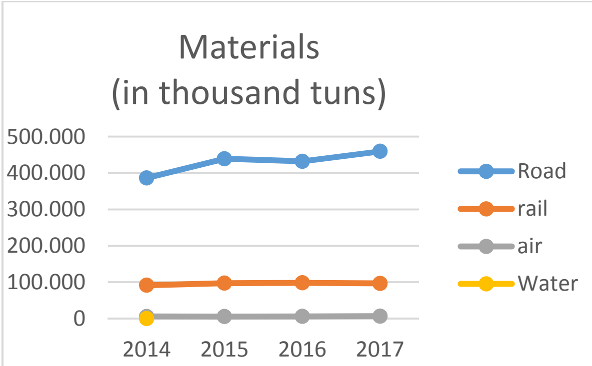

Figure 1: Development of transported goods in the Czech Republic in individual transport sectors.

Material transport is specific not only to the customer but also to the carrier. For the customer, the price and the date of delivery are important. For transporters, there are customer requirements to satisfy their needs. The growth in the transport sector is due to the fact that it is the only way to get material from point A to point B. the more material that is transported, the more means of transport we need. In order to reverse this trend, we are working on a tool that will reduce the number of means of transport, thereby increasing the safety.

4. CASE STUDY

The case study is focused on describing the phases on which the tool is built. The first phase is transport planning. Transporting transport units is a very static function during the planning phase. During planning, it is possible to respond to already planned reconstructions, closures or transport of oversized cargo, which restrict traffic on the routes on which they move. The planning phase is important for each shipment to meet customer requirements, but at the same time, the cost of the successful completion of the transport route and the goal is calculated.

The second phase is called the transport process. The second phase is more interesting because it works in real time. It responds to incidents or crisis situations that have not yet occurred or are already on the planned route. The instrument should evaluate incidents or crisis situations that may arise based on the information obtained, eg traffic density, average speed, etc.

4.1 Planning phase

The planning phase is at the very beginning of the process. The planning phase is an important step towards the entire implementation of the transportation process. When planning, we set up input data that is an essential part of the functionality of the proposed tool.

Currently, we are working on improving the amount of input data that the tool operator should set. The current data in the proposed tool are as follows:

- Type of transport unit.
- Standardization of the type transport unit.
- Disposition of the transport unit.
- Dimension of goods.
- Transport packaging.
- Packaging characteristics and restrictions.
- Categorization of the transport environment.
- Other specifications and numeric operations.

After registering the input data in the planning phase of the tool, options are displayed. The situation is similar to the route planning for navigation. The big difference is the need to register a larger amount of input data in order to avoid complications such as a lower underpass, a bridge that does not meet the weight of the means of transport or navigation around water tanks in a dangerous transport unit.

The options are shown on figure 2. From the selected options, we will choose the most suitable solution. For our case study, we chose ROAD # 2.

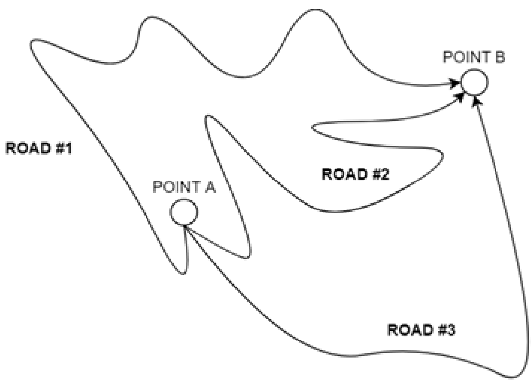

Figure 1 Select the appropriate route.

The picture shows that there were more options and it is purely up to the operator which route they choose as the most suitable. In the planning phase, there are possible routes on which there may be no restrictions but vice versa. There may be some restrictions on each route that is acceptable and it is up to the operator to evaluate it correctly. After evaluating and selecting the route to be completed, we will proceed to the next point. At this point, we manage the real-time shipping process.

4.2 Real-time transport management

In this section, we will discuss the functionality of the tool. The tool monitors and displays the route selected to complete the route. During the transport process, the operator is exposed to risks on the route and, if necessary, opens up other options for switching to another route. Figure 3 shows a situation that alerts the operator during the transport process. The vehicle picked up the shipment or material and chose the chosen route. During the transport process along the selected route, a crisis situation arose. This situation occurred on the planned route.

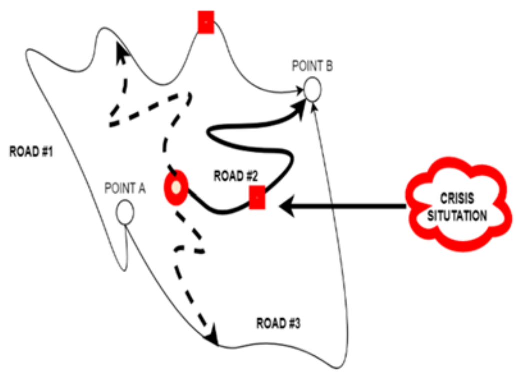

Figure 2: Alternative solution to the situation.

A road accident occurred during the transport causing a 2 hour delay in navigation. Based on this event, traffic is redirected to alternative routes. These routes do not take into account the characteristics of the transport units. There is a diversion regardless of the material transported. Therefore, categorization of cargo is not taken into account, which can endanger human health and the proper functioning of critical infrastructure elements due to increased risk of crisis situations.
Immediately following an obstacle on new route, the operator or dispatcher receives a problem report via the system. This phenomenon is shown in Fig. 3.

Upon receiving a crisis alert, the operator receives a solution to the most appropriate diversion solution. The turn to alternative routes is to reach point B. Customer input requirements are a priority in making decisions. The aim is to keep the deadline when the transport unit is to be in point B in spite of a crisis situation. When creating solutions and designing alternative routes, all input data are taken into account. The aim is to avoid threats or other risks in an environment where the vehicle will move with the transport unit..

All alternative solutions draw attention to the risks associated with input settings. If we have used a means of transport greater than 3 meters at the entry, this will be risk points. Due to the small difference in our ability to reduce or create another barrier.
Accurate specification of input data, as far as possible, will help the system to create the most appropriate and acceptable way to deliver successfully.

CONCLUSION

The amount of material that is transported daily increases every day. Transport of material by road is necessary not

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only for import and export of goods. Entrepreneurs increase their profits by means of transport and at the same time the situation in the territory in which they do business is improved. Transport-based residents have the possibility of commuting to work, various leisure activities and school responsibilities. Given the wide variability of road transport, this trend will not change and dynamic management should ensure greater safety for the population.

Critical infrastructure elements provide comfort not only for the population but also for the whole country. Each of the elements is included in the list of critical infrastructure elements that meet the sectoral and cross-cutting criteria. Every critical infrastructure sector is important to the state. Its functionality and safety assure the population a normal life without the occurrence of an extraordinary event. If one sector fails, another sector may become paralyzed and linked to each other by direct or indirect links. These links are important in reactivity to prevent eventual minimization of the consequences of a crisis or emergency.

Critical infrastructure elements are interconnected. In the event of a crisis situation, this risk may increase and threaten another element. This phenomenon can spread through a domino effect such as Blackout.

The proposed system should be able to respond to a large number of crisis situations in real time. The proposed system should be able to respond to incidents or crisis situations at both the planning and transport stages. Reacting in real time increases the security of the state and of the population. Its advantage is to create a safe environment after which a particular transport unit will be transported. By setting the correct and comprehensive input data, it is possible to react quickly to crisis situations in real time. The response will ensure that additional risks are minimized and could be further aggravated.

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