# Conceptual Model of Information System for Drone Monitoring of Trees' Condition

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Abstract. Goal is to create a system that will be analyze trees' condition using results from scanning and other obtained data and define options for damage detection. The project aim is the improvement of city management efficiency based on development of decision-making support systems according to the results of monitoring and analysis of urban environment parameters. In order to achieve the research aim will be developed technologies and methods for collecting, accumulation and presentation of urban environment parameters. Developed concept of visualization and methods for analysis of parameter's dynamics from drones sensors.

**Keywords.** Green Smart Cities, Drone, Drones Monitoring, Infocommunication, Computer Science, Sustainable Urban Development, Secure Society.

#### 1. Introduction

Tree monitoring information system using current technologies is topically for today. Such area is not fully researches in our county, but is very useful for future development. This system can make easier to look after trees and find options for improving its condition. Ecology can become better through it. Currently, the deterioration of the green space due to radiation exposure is increasing, as well as the number of pests and trees' dying. Scientists are working on preparations for improving trees' condition, but another important step is the collection of information about trees diseases and other damages and making statistics. The availability of up-to-date data on the state of the forest fund is an important prerequisite for effective management of forestry production. With the further development of new technologies, everyone will be able to determine the trees' condition. And also evaluate treatments or felling to improve the

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health of the green space. Obviously, this will increase the greening of the environment. There are currently several studies on tree monitoring. One of them was the use of forest inventory database and satellite imagery Sentinel-2 for classification of tree species composition on forested area. In the article they applied technology for mosaicking satellite images obtained during the one growing season in a form of cloudless composite image and used an algorithm that implies an analysis of satellite images Sentinel-2. The classification algorithm Random Forest allowed us to achieve an accuracy of 95% for classification of forested areas with a predominance of pine trees that dominate across the research area. [1]

Moreover, scientists are working on new methodology: forests laser scanning. This methodology identifies a more accurate carbon stock in forests, which is an important contribution to carbon stock monitoring and global climate policy. Laser measurements are used to accurately determine the size of a tree, its density, and from this you can find out the weight of the wood. This technology is called LiDAR (Light Detection and Radar) and the data obtained by this technology provides accuracy 90%. [2]

Special cameras such as hyper and multispectral cameras are coming to the market. They provide more opportunities for high-quality images of the green area. The hyperspectral camera emits different wavelengths of light in the visible and near infrared part of the electromagnetic spectrum, and visualizes it after the light is reflected from the surface of the object. This will allow you to determine the chemical composition of the object in this confrontation, because each chemical "shines" in its own way. The multispectral camera captures the light reflected by the plants in four separate parts: green, red light and two bands of the infrared spectrum. This makes it possible to provide a green space health. Another work in the industry is the Znaydeno startup, which can monitor deforestation and promptly notify it. This way, control bodies, the public, activists and journalists will be able to see where the cutting is happening. This will help establish whether or not it is legal [3]. All the research done in this area is a marvellous development of technology for ecology. But they only work to analyze the images, not to detect trees' damage and find solutions for improving their condition.

### 2. Analytical Review of Literary and Other Sources

According to the statistical analysis, the proportion of urban population in the world is constantly increasing and by 2017 it was 54.9% [1-5]. At the same time, this percentage is much higher in Ukraine - about 70% [6-8]. In addition, in Ukraine, due to many years of inadequate funding, municipalities are unable to effectively address growing problems, in particular:

- High level and increasing pollution of the urban environment (air, soil, water, noise pollution, electromagnetic pollution, etc.);
- Uncontrolled growth of illegal construction and the need for periodic monitoring of its pace, updating cadastral registries of land plots;
- Saturation of urban and suburban roads by vehicles, insufficient quality of road surface (traffic congestion, emissions of motor vehicles, noise, etc.);

- - Insufficient green spaces and illumination imbalance (during the night, individual areas are extremely bright, others are insufficient or not at all);
- - Growth rates of wear of cultural and historical facades of buildings.

Thus, in Ukraine, there are a number of topical problems in the management of cities, which greatly lead to economic losses of city budgets and negatively affect the quality of life of urban residents - increasing morbidity and mortality and slowing down the pace of economic growth of businesses and industrial enterprises. At the same time, decentralization reform in Ukraine actively implementing from 2016, which allowed municipalities to increase the budgets of their cities. That is why the task of improvement of city management efficiency is height relevant and original. Obtained solutions can be implemented by the German partners to increase the efficiency of the Germanise municipalities. The range of use of unmanned aerial vehicles in the civilian sector is not limited. However, flying is complicated by the current state of the legal framework for the use of airspace. For the benefit of the city, drones can be used in the following areas:

- Conducting search operations;
- Geological exploration;
- Aerial survey of the terrain;
- Performance of aviation chemical works;
- Monitoring of territories and objects;
- Video surveillance.

Drones have several advantages over manned aircraft, namely:

- To perform the same tasks, drones cost much cheaper manned aircraft, which need to be equipped with life support systems, protection, air conditioning, etc.;
- It is necessary to train pilots, and it costs big money and considerable time;
- The absence of crew on board significantly reduces the cost of performing a task, and increases the payload of the apparatus;
- Unlike manned aircraft, drones do not need airfields;
- The automatic and semi-automatic control reduces the influence of the human factor when performing the task.

Drones have been winning the fight for the heart of agrarians for several years and cease to shock the peasants by flying over the fields. However, many entrepreneurs choose imported equipment, despite the wide selection of domestic Ukrainian machines. The drone carries a special spectral camera, shoots, and then these images are stitched into the appropriate map (NDVI). In addition, you can see right away, for example, where the field is under-moist, where the vegetation is poorly developed, say, through weeds, or where the parks are damaged. Therefore, there is no need to use fertilizers where they are superfluous, and it is possible to carry out "spot" processing. Such processing can also be carried out with the help of copters of Ukrainian production. The aircraft arrives at the problem spot and sprays the necessary fertilizers or pesticides. The competence of such machinery also includes crop protection, monitoring during harvesting, accurate field sizing, and timely erosion prevention.

The task of monitoring of the urban environment is being best solved by the concept of Smart City [9-14]. One of the most important tasks, as part of the Smart City concept, is to control and ensure the quality of an urban environment where a person is supposed to spend most of his life [15-19]. Most active this concept implemented in Kyiv, Lviv, Kharkiv, Ivano-Frankivsk, Vinnytsia and Dnipro. For example, in Lviv municipality, the city's geoportal was developed and widely used. However, the Lviv geoportal provides statistical information and does not allow to measure and show urban parameters in dynamics. For cities with a well-established structure, it is typical to solve individual problems. In particular, such as [1-9]:

- Street monitoring with the help of stationary cameras,
- Intelligent traffic lights for traffic management,
- Search for parking places,
- Monitoring of individual parameters of the urban environment using stationary sensors (temperature, humidity, etc.), etc.

However, the installation of stationary sensors in the city to control the set of parameters involves significant investment and may not always be available for city budgets [20-27]. One of the alternatives is the use of unmanned aerial vehicles, in particular drones of a copter type [28-31]. They have a number of significant benefits: high mobility; possibility of use in hard-to-reach places; possible assembly of different sets of sensors according to the task; a wide range of tasks - from monitoring of selected environment parameters to video surveillance and mapping tasks; relatively low cost of operation. The use of drones in the monitoring and mapping tasks provides a *significant economic effect* [32-38]. It is difficult to estimate it in numbers. However, for example, the cost of using drones in the tasks of constructing cadastral maps is considerably less than when using planes or helicopters, while ensuring higher quality and accuracy of the received images [7-19]. That is why using of drone for obtained urban parameters' dynamics is *highly relevant* [39-47].

#### 3. Characteristics of drones

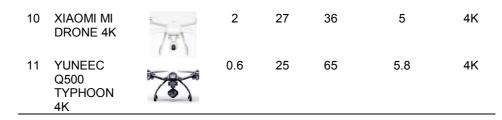
The drone shall include in its composition to provide real-time monitoring of the city in the course of flight and digital photographing of selected areas (including inaccessible areas, as well as determining the coordinates of the investigated sites):

- Satellite navigation system (GPS);
- Command line navigation devices with antenna feeder device;
- Device for sharing command information;
- On-board digital computer:
  - Block of inertial navigation system;
  - Satellite navigation receiver (SNR);
  - Autopilot unit and air speed sensor;
  - o Flight data storage.

The complex is compatible with radio channel pulse code modulation (PCM). It allows you to control the drones in manual mode from a standard remote control, as well as automatic on autopilot commands. Autopilot is able to simultaneously stabilize flight and control navigation. This eliminates the need for a separate stabilization system. Autopilot supports fly-bywire mode. The board is designed on the basis of at least 16 MHz microcontroller. The controller communicates with an analogy receiver. Drones, which has a high degree of manoeuvring and controllability, simple design and can perform many different functions, require relatively simple management skills at relatively low cost. Once of drones were used only by the military, for reconnaissance. Now, everyone can buy drones. You can take the same photos or even better with the help of top aerial drones (Table 1).

No	Name	Photo	Range of control (km)	Flight time (min)	Flight speed (km/h)	FPV (GHz)	Camera
1	DJI MAVIC 2		8	31	72	2.4/5.8 (OCUSYNC 2.0)	4K
2	DJI INSPIRE 2	FSM	7	25	93	2.4/5.8 (OCUSYNC 2.0)	4K/6K
3	DJI PHANTOM 4 PRO V2.0		7	30	72	2.4/5.8 (OCUSYNC)	4K
4	DJI MAVIC PRO	6 PL	7	27	65	2.4/5.8 (OCUSYNC)	4K
5	AUTEL ROBOTICS EVO		7	30	65	2.4	4K
6	DJI MAVIC AIR		4	21	68	2.4/5.8 (WI- FI)	4K
7	gopro Karma		3	25	60	5.8	-
8	AUTEL ROBOTICS X-STAR		2	25	72	5.8	4K
9	YUNEEC TYPHOON H		1.6	25	70	5.8	4K

Table 1. General information about drone types and their features



Drones are mainly chosen for the quality of shooting and high-speed FPV flights. When selecting racing drones, first of all, attention is paid to the frame size, the used flight controller, the power of the motors, and such a criterion as the range is practically not taken into account, since flights are carried out mainly at short distances. High-quality photo and video shooting is good. But in addition to the workmanship, size, autonomous properties and shooting quality, an important criterion is the flight range with a large radius of action and a camera.

Drones are relevant in various fields of activity. For example, it is a traditional way of monitoring transmission lines and the condition of bridges. The ability to mount a variety of hi-tech equipment on the copter extends their scope. For example, laser scanners make it easy to accurately evaluate the terrain and create 3D models of it. A good tool, for example, for the mining industry, where you always need to know the status of quarries, the amount of ore mined, or other production parameters. Great prospects for such equipment in security activities, or simply by organizing a security system for any enterprise with a large area. When it comes to new uses of drones, the delivery of goods comes to mind immediately. Although there is no regulatory framework in place to qualify the use of drones, it is a matter of time. Therefore, in any industry where you need to study, observe and respond quickly and transport something light, drones will perform more efficiently than other devices.

Ukraine is proud of what it is. The research and production complexes that created a number of successful models for the army have now been "switched" to developing machines for business use. Today in Ukraine it is already possible to order both light and easy to use drones for aerial reconnaissance and aerial photography, as well as heavy multi-rotor platforms of high load capacity for various applications. These can even be "tethered" aircraft that are powered from the ground with virtually unlimited flight time for observation, signal relaying, and more. Today we can talk about several Ukrainian teams that create their drones specifically for agriculture and industry, namely: MegaDrone, ITEC, Drone.UA, AgriEYE, Matrix UAV, Kray Technologies, AeroDrone and AgroDrone. More than 10 companies in Ukraine are involved in the development and production of drones. Half of them have a level not worse than the world's manufacturers. The most famous and powerful Ukrainian manufacturers are Drone.UA, a leading integrator of unmanned technologies in the Ukrainian market. This company has quickly gone from a start-up to a manufacturer of the widest range of drones for business.

Drones of the Ukrainian company Kray Protection have the highest performance, load capacity and speed in their class. This manufacturer's drone helps to bring about 70% of the plant protection products and growth regulators used in agriculture.

Kiev Company ITEC has begun its journey into the production of reconnaissance drones. Today, ITEC is releasing not only the Army Patriot, but also SKIF, a model

designed for agriculture. It is the most automated and protected drone in Ukrainian production. Easy to use, high performance. It fully meets the needs of large producers and agricultural holdings. MegaDrone is a young team from Lviv. The company produces SkyHunter MD-1 and MD-2 aircraft. With their help, you can create orthophotos, make a trichogram, measure fields and calculate vegetation indices (for example, in the Drone Deploy data processing service). In addition, these are practically all the main tasks that agronomists are facing today. Finally, the company Matrix UAV, which appeared in the volunteer movement, finally completes the rating of domestic producers. Its "Katana" was created as a military drone, but due to its characteristics found a place on the agricultural market. A heavy multifunctional Commander platform has been created on its basis for the introduction of PPPs.

Power issues are one of the main issues in the creation of drones. In addition, they decide it differently. These are batteries, internal combustion engines, hybrid systems, and tethers. Each of these types has its advantages and disadvantages. Therefore, any energy-efficient invention is a gift for drone developers. According to DronUA, solar drones have already begun to be used in Ukraine. In the future, this will allow the copters to be in the air for an unlimited amount of time, since the battery life will be restored directly during operation. Daytime charging - Accumulated charge is spent at night. What will it give? Larger observation areas and significant monitoring timesavings. Owners of devices weighing over 2 kg and those flying above 50 meters above the ground now need to coordinate their flights with the State Aviation Service. On June 1, a new procedure for the use of airspace entered into force in Ukraine, by which the State Aviation Service substantially restricted the use of drones. First, this applies to devices weighing more than 2 kg and those flying above 50 meters above the ground. They now need to coordinate their flights with the appropriate services. In addition, the penalties for violation of the rules are quite severe. However, at the same time the State Aviation Service stressed that they are ready for dialogue, because they understand that progress is inevitable, and the use of drones is not only necessary but also sometimes necessary. The rules of the game (or rather, the air traffic) will eventually confirm, as technologies are actively evolving, drones are gaining more opportunities and becoming more accessible to businesses. Further development of the drone market will be facilitated by the spread of precision farming practices and the resource efficiency of production.

#### 4. Advantages of using drones to monitor urban change

**Speed and economy.** Aerial photography is still the most productive method of documenting terrain. Previously, aerial photography was only carried out using large aircraft. This approach was accompanied by some limitations. It was not economically feasible to take aerial photography of small objects, and the resolution of the images was highly dependent on regulatory and technical restrictions on the use of the aircraft and airspace. The appearance of drones changed everything. Whether it's a small town, or a construction site or hydraulic drones, everything will be removed.

**Details and completeness.** Looking from above always made it possible to evaluate the situation more comprehensively, to see the hidden, to see the changes. Aerial photography using a UAV (UAV) allows you to get images with a resolution of less than 1 cm per pixel. The required (appropriate) detail of the shooting is determined by the objectives of the project or study area. The ability to distinguish the smallest details in the pictures, their automated processing and analysis allow you to create intelligent geodata products that describe the terrain and the processes taking place on it. Each pixel of the image may contain critical terrain or object data, so our operators are focused on getting the customer the most detailed and complete view of the terrain. All our projects are accompanied by field aerial photo decoding processes, that is, in addition to images, we provide our client with a situational plan and description of POIs that cannot be obtained from the air.

Quality and safety. Achieving the expected quality parameters of the end products is based on the professionalism of the operators, the technical capabilities of the UAVs and cameras, compliance with the technical requirements and quality control of each stage of the work. Operators must have extensive experience not only in aerial photography, but also in surveying, photogrammetry, mapping and 3D modelling. The project begins with a very careful planning of the shooting routes and their overlap, as these parameters have a critical impact on the accuracy and quality of the final product. The best option will be chosen depending on the project goals, the configuration of the subject, the requirements for the end result, the timeframe and the expected cost. In order to achieve the required parameters of aerial photography accuracy, a project of altitude anchoring is being developed, which guarantees the necessary reliability of data and the requirements of the current instruction and regulations regarding the accuracy of finished mapping products. Professional UAVs and cameras must be used for aerial photography. Using dual-frequency GPS, PPK / RTK technologies, large-matrix cameras, and distortion-free lenses and chromatic aberrations, stereodigitization allows you to easily meet topographic scale plans of 1: 5000 - 1: 1000 and partially 1: 500. The results of aerial photography pass the field control of the accuracy of the finished product. Compared to an airplane or helicopter, our drones are small in size, have no fuel on board, are equipped with a parachute system and duplicate navigation systems, and can not damage infrastructure and structures. All aerial photography works are in agreement with UkSATSE, and the company and operators must have permission to work with state secret information.

**Flexibility and complexity.** Aerial photography results are the basis for the production of numerous derived geodata products that can be used for various areas of client's professional activity: design, construction, audit and documentation, monitoring of changes, development of land and town planning documentation, analysis of risks of man-made and natural origin, imitation investor search and more. The method is to focus on the complexity of the solution and the flexibility to meet customer needs. For this purpose, besides collecting the main data set, it is necessary to use the offered expert approach and involvement of leading specialists in the necessary fields. A thorough understanding of technology allows you to combine a variety of data from aerial photography, cartography, laser scanning, bathymetric surveys, geodetic monitoring, geological surveys and hydrodynamic modeling into a single model. The flexibility of UAV-based technologies allows you to complement and enhance any project by quickly and inexpensively producing up-to-date, detailed, and reliable onpremises object data without the hassle of accessing and research-related risks. Of course, solutions based on the use of UAVs (UAVs) have certain technological limitations. But for a quick and high-quality assessment of the situation on the ground, the use of drones is the best solution.

## 5. Detailed description of the project

System analyzes trees' condition of researched object such as forest area, park territory, smallholding and others. System find options for improving trees' condition and do collection and analyzing data [48-59]. The main processes that system does:

- multi and hyperspectral, laser cameras scan the territory;
- compares and analyzes obtained data from result of scanning and client's previous researches and statistics;
- defines trees' diseases, pests and others damages;
- find options for improving trees' condition and damage prevention options for trees;

The system context diagram according to IDEF0 methodology (Fig. 1).

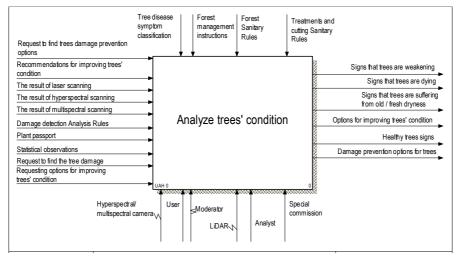


Fig. 1. IDEF0 context diagram

System decomposition (Fig. 2) and its activity definition (Table 1).

Table 2. Activity definition for IDEF0

Activity Name	Activity Definition
Make trees' characteristics according to the pattern	Make trees' characteristic according to obtained scanning result data.
Compare the obtained data	Compare characteristics with plant passport and tree disease symptoms.
Analyze the data for damage detection	Analyze all obtained data for damage detection and tree disease.

Find options for improving trees' health	Define prevention, selective felling or clear-cutting for		
	improving trees' health.		

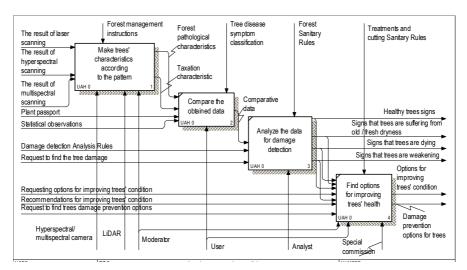


Fig. 2. IDEF0 decomposition diagram level 1

Decomposition for process "Make trees' characteristics according to the pattern" (Fig. 3) and its activity definition (Table 2).

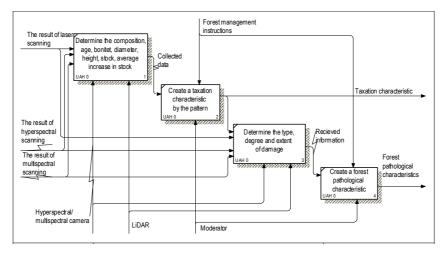


Fig. 3. Decomposition diagram level 2 for process "Make characteristics of trees according to the pattern"

The system context diagram according to DFD methodology by Gane and Sarson notation (Fig. 4) and its decomposition (Fig. 5).

Table 3. Activity definition for process "Make characteristics of trees according to the pattern"

Activity Name	Activity Definition
Determine the composition, age, bonitet, diame-	Define all trees' properties and parameters from
ter, height, stock, average increase in stock.	the scanning results.
Create a taxation characteristic by the pattern.	Make a taxation characteristic by the pattern from the collected data.
Determine the type, degree and extent of dam- age.	Define all trees' type, degree and extent of damage from the scanning results.
Create a forest pathological characteristic by the pattern.	Make a forest pathological characteristic by the pattern from the received information.

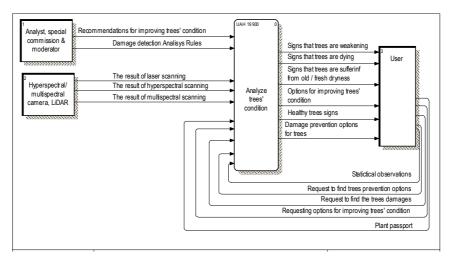


Fig. 4. DFD context diagram by Gane and Sarson notation.

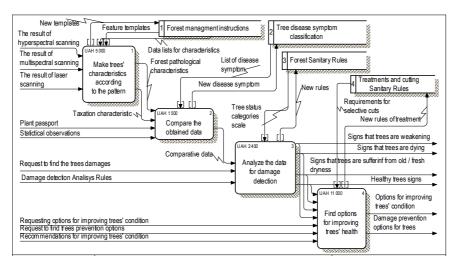


Fig. 5. Decomposition diagram level 1.

Processes decomposition: "Make trees' characteristics according to the pattern" (Fig. 6), "Compare the obtained data" (Fig. 7) and its activity definition (Table 3), "Analyze the data for damage detection" (Fig.8) and its activity definition (Table 4), "Find options for improving trees' health" (Fig.9) and its activity definition (Table 5).

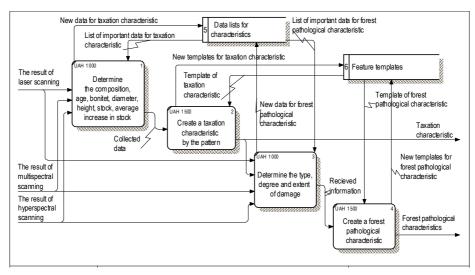


Fig. 6. Decomposition diagram level 2 for process "Make trees' characteristics according to the pattern".

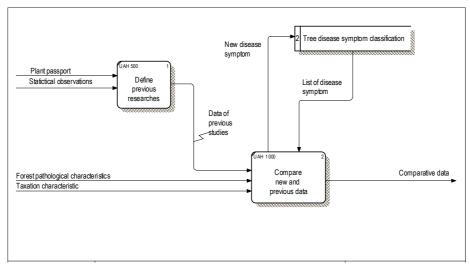


Fig. 7. Decomposition diagram level 2 for process "Compare the obtained data".

Table 4. Activity definition for process "Compare the obtained data"

Activity Name	Activity Definition
Define previous researches	Define previous damages, trees' state and its properties from plant passport and statistical observations.
Compare new and previous data.	Compare characteristics with plant passport, tree disease symptoms and obtained data of previous studies.

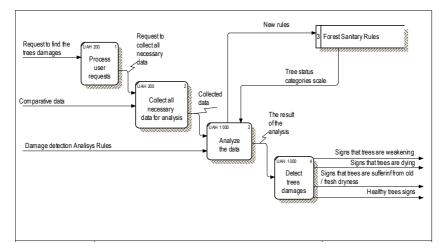


Fig. 8. Decomposition diagram level 2 for process "Analyze the data for damage detection".

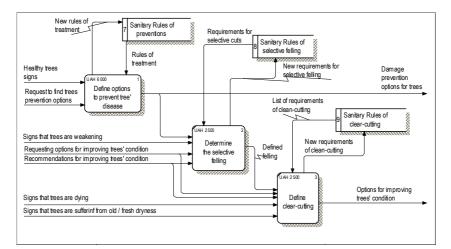


Fig. 9. Decomposition diagram level 2 for process "Find options for improving trees' health".

Table 5. Activity definition for process "Analyze the data for damage detection"

Activity Name	Activity Definition		
Process user requests	Verifying user's request and proceeds to the appropriate step.		

Collect all necessary data for analysis	Collect all data as characteristics, comparative data, plant pass- port and statistical observations.
Analyze the data	Analyze collected data for damage detection.
Detect trees damages	Detect trees damages such as weakening, dying, old/fresh dry- ness or healthy signs.

Table 6. Activity definition for process "Find options for improving trees' health"

Activity Name	Activity Definition
Define options to prevent tree disease	If trees are healthy, it is necessary to define prevention to avoid tree disease
Determine the selective felling	If trees are weakening, it is necessary to determine and do the selec- tive felling for removing trees' damages and making them healthier.
Define clear-cutting	If trees are dying or suffering from old/fresh dryness, it is necessary to determine and do the clear-cutting for removing all trees because there is no better way.

Node Tree diagram by displaying the lower level in the form of list (Fig. 10).

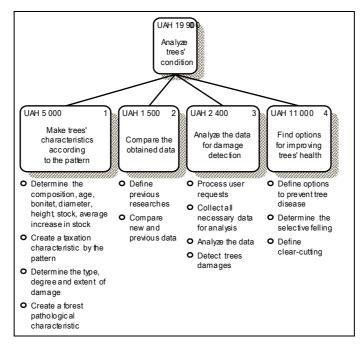


Fig. 10. Node Tree diagram by displaying the lower level in the form of list.

FEO diagram that has the other point which shows the analysis trees' condition when input data are information about fire damage, technogenic impact, damage due to natural and man-made phenomena. So there is the same process "Find options for improving trees' health" (Fig.11).

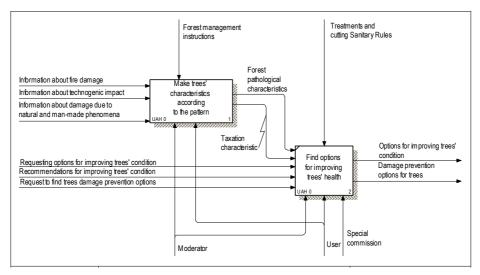


Fig. 11. FEO diagram

IDFE3 diagram of decomposition level 3 for process "Define options to prevent tree disease". There are two types of intersections: asynchronous OR in branching because all processes can begin in different way and synchronous OR in the merge because all active process must end together for activating the next process (Fig.12). IDFE3 Scenario diagram (Fig.13).

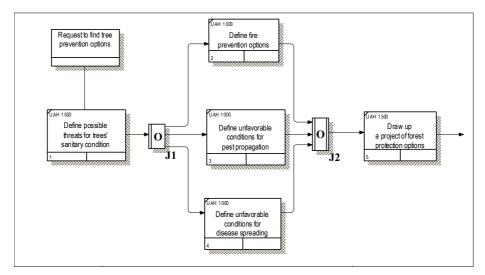


Fig. 12. IDFE3 diagram of process decomposition.

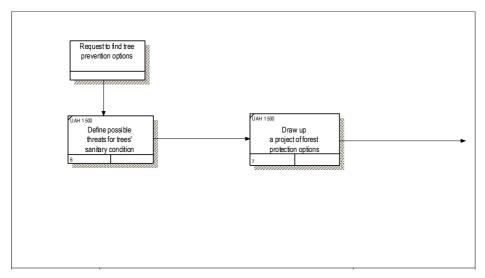


Fig. 13. IDFE3 Scenario diagram

Activity cost report. In this case, the total cost is determined by 1 m2 of trees planted (Fig. 14).

Файл <u>Редагування</u> Фор <u>м</u> ат <u>В</u> и	гляд Довідка				
Ictivity Number	Activity Name	Activity Cost (UAH)	Cost Center	Cost Center Cost (UAH)	
1	Analyze trees' condition	19 900,00	Analyze the data	1 000,00	
			Collect the necessary data for analysis	200,00	
			Compare the data obtained	1 000,00	
			Define clear-cutting	2 500,00	
			Define damages	1 000,00	
			Define data of previous researches	500,00	
			Define selectine felling	2 500,00	
			Define the amount of damage	1 000,00	
			Define tree properties	1 000,00	
			Fire fighting measures	1 000,00	
			Forest pathological characteristic	1 500,00	
			Possible tree threats	1 500,00	
			Process user request	200,00	
			Project of forest protection measures	1 500,00	

Fig. 14. Activity cost report.

#### 6. Conclusions and Development Prospects

The proposed tree monitoring system has a great deal of functionality. There are the analysis of the obtained images from the cameras, the comparison of the data and the analysis for the detection of damage to the green space, which is especially important for the tree monitoring. In addition, the system will find measures to improve the condition of trees formed on the basis of the requirements and guidelines of the special commission, and will not need to involve additional experts in the field of forestry. The data collected is an up-to-date information for the study of green space, which will allow to further create statistical observations and find new solutions to tree damage.

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