# MODELIRANJE PROJEKTNIH RIZIKA U RAZVOJU PROJEKTA VJETROELEKTRANE

# MODELING PROJECT RISKS IN THE DEVELOPMENT OF A WIND POWER PLANT PROJECT

Mr. sc. Filip Mužinić, Končar-KET,
Fallerovo šetalište 22, 10000 Zagreb, Hrvatska
Prof. dr. sc. Davor Škrlec, Sveučilište u Zagrebu,
Fakultet elektrotehnike i računarstva,
Unska 3, 10000 Zagreb, Hrvatska

Projekt izgradnje vjetroelektrane je višegodišnji složeni projekt, tijekom kojega su sve zainteresirane strane izložene brojnim rizicima od kojih su neki dovoljno značajni da mogu upropastiti projekt. U radu je predočena metodologija modeliranja projektnih rizika u razvoju projekta vjetroelektrane uvažavajući specifične okolnosti u Republici Hrvatskoj. Primijenjena metoda analize rizika pripada skupini probablističkih metoda koje koriste Monte Carlo simulacijsku analizu. Detaljno su opisani identificirani rizici i način provođenja kvalitativne i kvantitativne analize rizika. Na primjeru analize rizika projekata vjetroelektrane 20x1 MW objašnjeni su i ugrađeni u model ekonomski kriteriji za donošenje odluka. Model za analizu rizika projekata vjetroelektrana u Republici Hrvatskoj izrađen je u Microsoft Excelu i namijenjen je donositeljima odluka i voditeljima projekata. Iako je referentni slučaj u modelu projekt vjetroelektrane u hrvatskim uvjetima, moguće ga je prilagoditi za bilo koje tržište.

The construction of a wind power plant is a complex project that requires many years, during which time all the interested parties are exposed to numerous risks, including some with potentially devastating consequences. In this article, a methodology for modeling project risks in the development of a wind power plant project is presented, taking into account the specific circumstances in the Republic of Croatia. The applied method of risk analysis belongs to the group of probability methods that use Monte Carlo simulation analysis. The identified risks and manner of conducting qualitative and quantitative risk analysis are described in detail. Using the example of the risk analysis of a project for a 20x1 MW wind power plant, the economic criteria for decision making are explained and incorporated in a model. This risk analysis model for the wind power plant projects in the Republic of Croatia is constructed in Microsoft Excel and intended for decision makers and project developers. Although the reference case in the model is wind power plant project in Croatia, it can be adapted to any market whatsoever.

Ključne riječi: Monte Carlo analiza, projektni rizici, vjetroelektrana
Key words: Monte Carlo analysis, project risks, wind power plant


https://doi.org/10.37798/2007564365

# 1 UVOD

Hrvatska ima znatne prirodne potencijale za razvoj projekata vjetroelektrana, a neke procjene govore o minimalno 400 MW komercijalno isplativih vjetroelektrana [1]. Hrvatska je u procesu pridruživanja Europskoj uniji, i prilagođavanje se događa na svim razinama pa tako i u elektroenergetici. Povećanje udjela obnovljivih izvora energije u hrvatskom elektroenergetskom sustavu određeno je kvotom od 5,8 % potrošnje do 2010. godine. Prema izračunu Ministarstva gospodarstva, rada i poduzetništva taj bi udio 2010. godine iznosio 1 139 GWh. Radi se samo o prvoj fazi izgradnje nakon koje će se planirati daljnje povećanje. Budući da trenutačno u Hrvatskoj gotovo da i nema obnovljivih izvora energije, pitanje je hoće li se tako kratak rok dostići, ali se zasigurno može očekivati intenziviranje aktivnosti u idućih 5 – 10 godina. Tehnologija korištenja energije vjetra kao najrazvijenija iz ovog spektra već sada preuzima vodeće mjesto u Hrvatskoj, što se očituje u velikom interesu za izgradnju vjetroelektrana u posljednjih tri do četiri godine. Potencijalni investitori su pokrenuli veliki broj mjerenja vjetrenih prilika na mogućim lokacijama, a prema nadležnim tijelima su upućeni brojni zahtjevi za priključkom vjetroelektrana. U 2007. godini u Hrvatskoj je stupila na snagu zakonska regulativa (potrebni zakonski podakti) koji omogućuju funkcioniranje tržišta obnovljivih izvora energije.

Projekt izgradnje vjetroelektrane je višegodišnji složeni projekt tijekom kojega su sve zainteresirane strane izložene brojnim rizicima od kojih su neki dovoljno značajni da mogu upropastiti projekt. Procjenjivati vrijeme trajanja faza projekta i troškove na temelju osjećaja nije samo neprofesionalno, već i opasno. Analiza rizika je potrebna da bi investitor i voditelj projekta što bolje predvidjeli i izbjegli buduće probleme.

# 1 INTRODUCTION

Croatia has significant natural potentials for the development of wind power plant projects. Some estimates speak of a minimum of 400 MW of commercially profitable wind power plants [1]. Croatia is in the process of accession to the European Union and adjustments are occurring at all levels, including the electrical energy supply. The quota that has been established for increasing the percentage of renewable energy sources in the Croatian electrical energy system is 5,8 % of total consumption by the year 2010. According to the calculations of the Ministry of the Economy, Labor and Entrepreneurship, this percentage would amount to 1 139 GWh in the year 2010. This concerns only the first phase of construction, after which further increases are planned. Since currently there are practically no renewable energy sources in Croatia, it is a question whether this goal will be achieved during such a short period. Nonetheless, intensification of activities can certainly be anticipated during the next five to ten years. The technology for using wind energy as the most developed of this spectrum has already assumed the lead in Croatia, as evident from the great interest in constructing wind power plants during the past three to four years. Potential investors have instigated large numbers of measurements of the wind conditions in potential locations and have submitted numerous applications to the authorized agencies for the connection of wind power plants. In the year 2007, legal regulations went into effect in Croatia (energy bylaws) that make it possible for the renewable energy sources market to function.

The construction of a wind power plant is a complex project that requires many years during which time all the interested parties are exposed to numerous risks, including some with potentially devastating consequences. Estimating the duration of the project phases and costs on a subjective basis is not only unprofessional but also dangerous. Risk analysis is necessary in order for the investor and project developer to anticipate and avoid future problems to the greatest possible extent.

## 2 INTERESNE STRANE I ODNOSI NA TRŽIŠTU VJETROENERGETIKE

S aspekta projekata vjetroelektrana postoje tri ključne kategorije aktivnosti. Interesne strane u projektu vjetroelektrane ponekad su specijalizirane za pojedinu djelatnost, a ponekad objedinjuju nekoliko njih:

- voditelj projekta (*developer*) – ima glavnu ulogu u projektu. To je poduzeće koje razvija projekte. Njihova aktivnost obuhvaća organiziranje projekta od traženja i odabira lokacije te mjerenja do puštanja u pogon i održavanja. Budući da je tržište vjetroenergetike relativno novo (ne samo za Hrvatske pojmove), voditelji projekta se najčešće bave i traženjem te privlačenjem investitora, organiziranjem investicije (u smislu pokretanja kredita i sl.), a rjeđe i eksploatacijom. Na njima ujedno leži i odluka o odabiru opreme (proizvođača). Voditelja projekta u Europi i svijetu ima mnogo, a većina europskih poduzeća je prisutna na hrvatskom tržištu kroz agente ili poduzeća kćeri,
- proizvođači opreme – uglavnom su uključeni u projekte posredno, budući da se najčešće specijaliziraju za proizvodnju. Ponekad se bave i djelatnostima voditelja projekta, iako je to većinom vezano uz testiranje opreme (prototipa koje nitko neće kupiti prije negoli se dokažu u praksi). Ako se proizvodno poduzeće odluči za bavljenje projektima, najčešće uspostavlja partnerski odnos sa zasebnim poduzećem – voditeljem projekta,
- investitori – vjetroenergetika većinom privlači privatni kapital, što znači da su investitori različiti i ne moraju biti vezani za energetiku. Uobičajeni vidovi financiranja, kao što su krediti poslovnih banaka, funkcioniraju i u projektima vjetroelektrana, ali banke nisu uvijek spremne pratiti ove projekte na odgovarajući način. U zemljama u kojima vjetroenergetika nije nova djelatnost postoje poduzeća koja su se specijalizirala upravo za financiranje projekata u vjetroenergetici i nude vrlo specifične financijske proizvode prilagođene toj djelatnosti. Većina projekata se barem parcijalno financira kreditima financijskih institucija pa su one nezaobilazne kada se govori o investitorima. Budući da se radi o projektima od političkog i javnog interesa (posebno u Europi), a koji ne bi zaživjeli bez poticaja, različite državne i međunarodne institucije su u velikoj mjeri uključene u financiranje (Europska banka za obnovu i razvitak – EBRD, Europska investicijska banka – EIB, Fond za globalnu zaštitu okoliša – GEF).

## 2 INTERESTED PARTIES AND RELATIONSHIPS ON THE WIND ENERGETICS MARKET

From the aspect of wind power plant projects, there are three key areas of activities. The interested parties in a wind power plant project are sometimes specialized in individual activities and may encompass several of them:

- the project developer – has the main role. This is the enterprise that develops the project. The developer's activity includes the organization of the project from the search for and selection of a location and measurement to placing the plant in operation and maintenance. Since the wind energy market is relatively new, not only in Croatian terms, developers most often are also engaged in seeking and attracting investors, the organization of investment (in the sense of initiating loans etc.), and less frequently in exploitation. They also have the responsibility of deciding upon the choice of equipment (manufacturers). There are many developers in Europe and the world, and the majority of European enterprises are present on the Croatian market through agents or subsidiaries,
- equipment manufacturers – mainly have indirect involvement in projects, since they are most often specialized in production. Sometimes they are also engaged in the activities of project developer, although in the majority of cases this is connected with the testing of equipment (prototypes that no one will buy before they are demonstrated in practice). If a manufacturing enterprise decides to become engaged in projects, it most often establishes a partnership with a special enterprise – a project developer,
- investors – can be varied and need not be connected with energetics, since wind power plants mostly attract private capital. The customary aspects of financing, such as loans from commercial banks, also function in wind power plant projects but banks are not always prepared to follow such projects in a suitable manner. In countries where wind energy is not a new activity, there are enterprises that are specialized precisely in financing wind energy plant projects and offer very specific financial products that are adapted to this activity. The majority of projects are at least partially financed by loans from finance institutions, which are unavoidable when speaking of investors. Since these are projects of political and public interest, especially in Europe, that would not exist without incentives, various countries and international institutions are involved in financing them to a great extent (the European Bank for Research and Development – EBRD, the European Investment Bank – EIB, the Global Environmental Facility – GEF).

Osim navedenih kategorija, postoji velik broj poduzeća koja se bave djelatnostima koje nisu izravno vezane za projekt izgradnje vjetroelektrane kao što su proizvodnja mjerne opreme, mjerenje vjetropotencijala, konzultantske aktivnosti, stručne analize itd.

In addition to the above categories, there are a large number of enterprises engaged in activities that are not directly connected with a project of constructing a wind power plant, such as the manufacture of measuring devices, the measurement of wind potentials, consulting activities, professional analyses etc.

## 3 ANALIZA RIZIKA

U posljednjih nekoliko desetljeća na tržištu je porasla potreba za upravljanjem rizicima (*risk management*). Za razliku od teorije odlučivanja, upravljanje rizicima usredotočeno je na proučavanje rizika kao ulaznih podataka za proces donošenja odluke. Upravljanje rizicima je dio upravljanja projektom (*project management*).

Postoje brojne definicije upravljanja rizicima od kojih je za potrebe ovog rada najprihvatljivija sljedeća: Upravljanje rizicima je korporativni i sistematski proces za procjenu i utjecanje na rizike i njihove posljedice na ekonomski najprihvatljiviji način, što uključuje adekvatno obrazovane uposlenike [2].

Određena vrsta upravljanja rizicima odvija se u svakoj organizaciji, bez obzira na njezinu veličinu ili djelokrug. Rizici su sastavni dio svakog poslovanja i projekta pa ih je nemoguće zanemariti, ali u većini slučajeva s njima se ne postupa organizirano. Navedena definicija podrazumijeva metodično upravljanje rizicima, nasuprot nasumičnom rješavanju problema i upravljanju rizicima kada se oni već manifestiraju. Organizirano upravljanje rizicima obično se sastoji od sljedećih koraka [1] i [3]:

- identifikacija rizika,
- analiza rizika,
- određivanje reakcija na rizike,
- promatranje rizika,
- izvješćivanje.

Navedeni popis nije konačan i pojedini se dijelovi manje ili više razlažu, ovisno o kvaliteti upravljanja rizicima i potrebama organizacije. Ovaj se rad primarno bavi analizom rizika pa su ostali dijelovi procesa zanemareni.

Analiza rizika može biti više ili manje složen postupak. Načelno ju je moguće podijeliti na kvalitativnu i kvantitativnu analizu, iako navedene etape variraju u detaljima, ovisno o odabranoj metodi analize rizika.

## 3 RISK ANALYSIS

In the past several decades, the need for risk management has grown on the market. Unlike the theory of decision making, risk management is focused on studying risks as input data for the decision making process. Risk management is a part of project management.

There are numerous definitions of risk management, of which the following is the most suitable for this article: Risk management is a corporate and systematic process for assessing and addressing the impact of risks in a cost-effective way and having staff with the appropriate skills to identify and asses the potential for risks to arise [2].

A specific type of risk management occurs in every organization, regardless of its magnitude and scope. Risks are an integral part of every operation and project, which are impossible to ignore, but in the majority of cases are not approached in an organized manner. The cited definition implies methodical risk management, the opposite of random problem solving and risk management when the risks are already manifested. Organized risk management generally consists of the following steps, [1] and [3]:

- risk identification,
- risk analysis,
- risk response,
- risk monitoring, and
- reporting.

This list is not final and individual parts more or less vary, depending upon the quality of the risk management and the organizational requirements. This article is primarily concerned with risk analysis, so that other parts of the process are neglected.

Risk analysis can be a more or less complex procedure. In principle, it can be divided into qualitative and quantitative analyses, although these stages vary in the details, depending upon the selected method of risk analysis.

### 3.1 Odabrana metoda analize rizika

Analiza rizika je složen proces koji je, ovisno o potrebama, moguće organizirati na različite načine. Postoje brojne institucije koje se bave standardizacijom upravljanja i analize rizika. Najraširenije metode analize rizika su [3] i [4]:

1) testiranje ekstremnih događaja (*stress testing*),
2) testiranje scenarija,
3) metoda srednji-optimistični-pesimistični slučaj,
4) analiza osjetljivosti,
5) *Value at Risk* (VaR metoda),
6) standard AS/NZS 4360 (Australija i Novi Zeland),
7) metoda PMBOK (*Project Management Body of Knowledge*, Project Management Institute – PMI, SAD).

Navedene metode rangirane su od jednostavnih od 1) do 4) prema složenijima od 5) do 7). Složene metode mogu sadržavati i neke jednostavne, kao fazu postupka analize rizika.

Cilj moderne analize rizika jest dati donositelju odluke preciznu informaciju sadržanu u gustoći razdiobe vjerojatnosti kriterijske varijable. Ovaj pristup je suprotan tradicionalnim metodama kod kojih se odluka donosi na temelju pojedinačne procjene, kao što je srednji-pesimistični-optimistični slučaj. Nadalje, metoda analize rizika mora omogućiti proces rigoroznog i logičkog računalnog modeliranja procesa kako bi se dobila razdioba vjerojatnosti kriterijske varijable.

Osnovni koraci odabranog procesa su:

1) identificirati kriterijsku varijablu i relevantne varijable koje na nju utječu,
2) opisati određivanje razdiobe vjerojatnosti za relevantne varijable,
3) ispitati i ustanoviti veze (potencijalne zavisnosti) između pojedinih varijabli,
4) ocijeniti razdiobe vjerojatnosti za sve relevantne varijable koje utječu na kriterijsku varijablu,
5) odrediti razdiobu vjerojatnosti kriterijske varijable koristeći Monte Carlo tehniku,
6) evaluirati projekt koristeći informacije sadržane u razdiobi vjerojatnosti kriterijske varijable.

Prema podjeli analize rizika na kvalitativnu i kvantitativnu analizu, koraci od 1) do 3) predstavljaju kvalitativnu analizu rizika, a 4) i 5) kvantitativnu.

Slika 1 daje shematski prikaz metode odabrane za analizu rizika projekata vjetroelektrana u Hrvatskoj.

### 3.1 The selected method of risk analysis

Risk analysis is a complex process that, depending upon the requirements, can be organized in various ways. There are numerous institutions that are engaged in standardization of risk management and analysis. The most widespread risk analysis methods are [3] and [4]:

1) stress testing (the testing of extreme events) ,
2) scenario analysis,
3) the mean-optimistic-pessimistic case method,
4) sensitivity analysis,
5) the Value at Risk (VaR method),
6) the AS/NZS 4360 standard (Australia and New Zealand),
7) Project Management Body of Knowledge – PMBOK, Project Management Institute – PMI, USA.

The above methods are ranked from the simplest, 1) to 4), to the more complex, 5) to 7). The complex methods may also contain some simple ones, as a phase in the risk analysis procedure.

The goal of modern risk analysis is to provide the decision maker with precise information contained in the density of the probability distribution of the criterion variable. This approach is contrary to the traditional methods, with which decisions are made on the basis of individual assessments, such as the mean-pessimistic-optimistic case method. Furthermore, the risk analysis method must facilitate a rigorous and logical computer modeling process in order to obtain the probability distribution of the criterion variable.

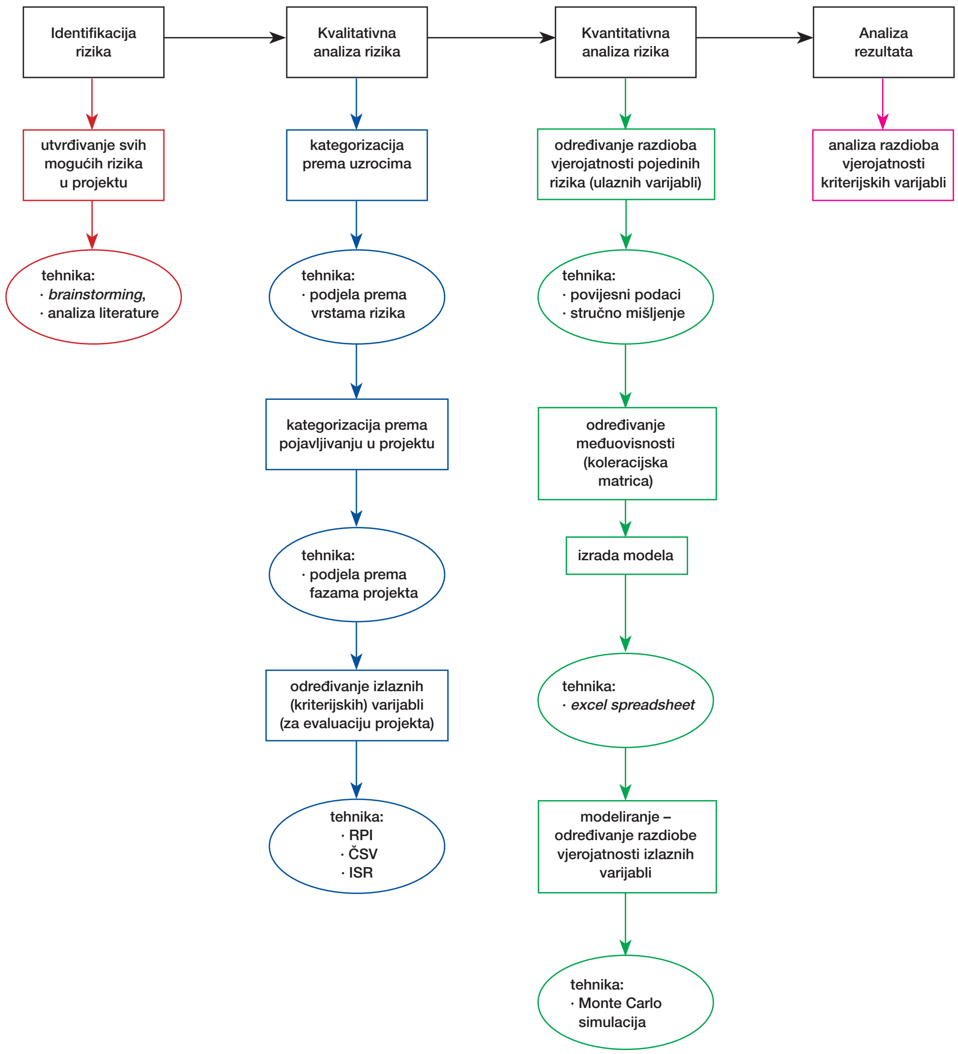
The basic steps in the selected process are as follows:

1) to identify the criterion variable and relevant variables that affects it,
2) to describe the determination of the probability distribution of the relevant variables,
3) to investigate and determine the connection (potential dependence) among individual variables,
4) to assess the probability distributions for all the relevant variables that affect the criterion variable,
5) to determine the probability distribution of the criterion variable, using the Monte Carlo technique,
6) to evaluate a project using information contained in the probability distribution of the criterion variable.

According to the division of risk analyses into qualitative and quantitative analyses, steps 1) to 3) represent qualitative risk analysis and steps 4) and 5) represent quantitative.

Figure 1 provides a schematic presentation of the method chosen for the risk analysis of the wind power plant projects in Croatia.

**Slika 1**
Prikaz odabrane metode za analizu rizika
**Figure 1**
Presentation of the method chosen for the risk analysis




## 3.2 Kvalitativna analiza rizika

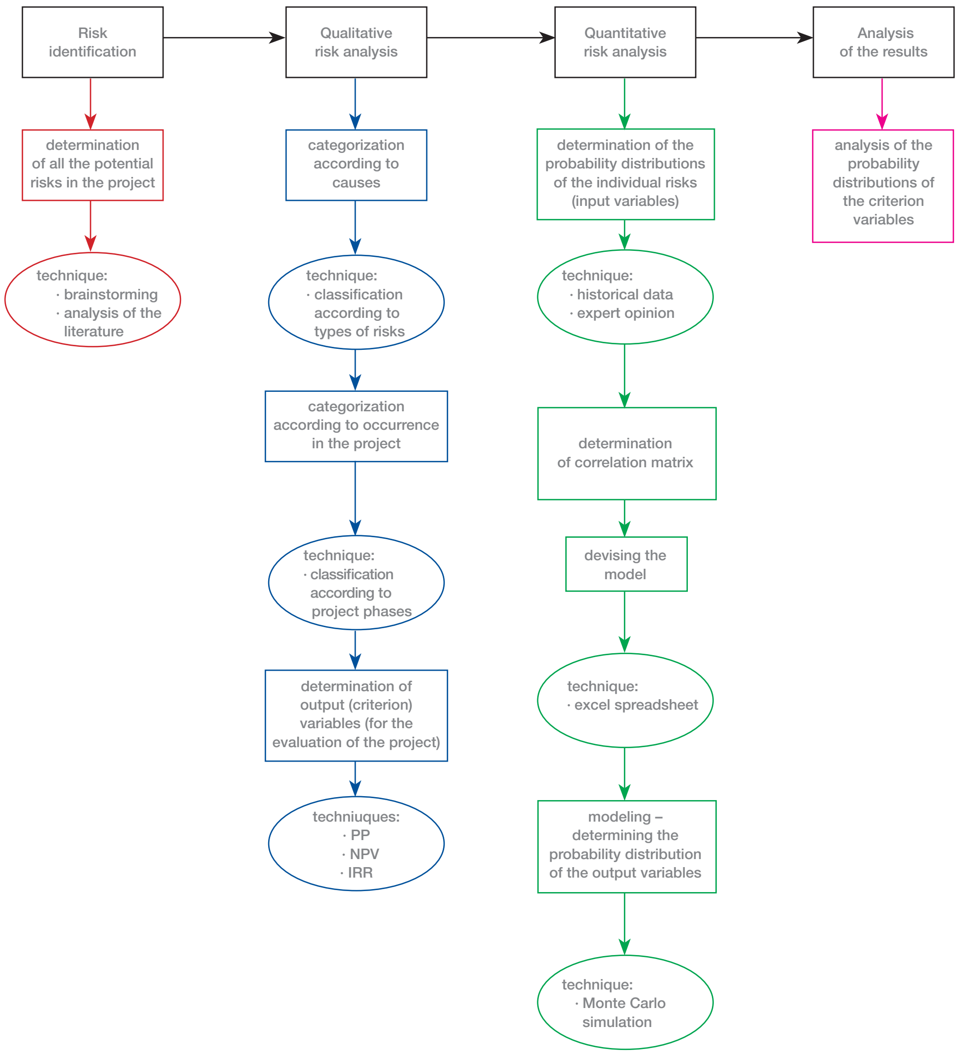
Kvalitativna analiza rizika uključuje različite metode određivanja važnosti identificiranih rizika i predstavlja pripremu za daljnju analizu, koliko god detaljna ona bila. Sastavni dijelovi kvalitativne analize su procjena utjecaja rizika na projekt i procjena vjerojatnosti pojavljivanja rizika, ali i tolerancija na rizik, troškovi itd.

Kvalitativna analiza može uključivati intervjuiranje stručnjaka i procjenu kvalitete dostupnih informacija o pojedinom riziku. Rezultate kvalitativne analize rizika potrebno je revidirati s vremenom, budući da se oni mijenjaju kako projekt odmiče.

## 3.2 Qualitative risk analysis

Qualitative risk analysis includes various methods for determining the importance of identified risks and represents preparation for further analyses, however complicated they may be. Assessments of the risk impact upon a project and the probability of risk occurrence, risk tolerance, costs etc. are integral parts of qualitative analysis.

Qualitative risk analysis can include the interviewing of experts and assessment of the quality of available information on an individual risk. The results of qualitative risk analysis must be revised with time, since they change as a project progresses.




Rezultati kvalitativne analize rizika mogu uključivati:

- ljestvicu rizika poredanih po utjecaju i vjerojatnosti pojavljivanja,
- grupiranje rizika prema kategorijama, bilo da se radi o njihovim uzrocima ili mogućim reakcijama na rizike,
- listu rizika koji zahtijevaju hitnu reakciju,
- praćenje promjena pojedinih rizika s vremenom.

Načini klasifikacije rizika su uistinu različiti i mnogobrojni. Podjele u prvom redu ovise o gledištu s kojeg se vrši analiza. Tako će se razvrstavanje i procijenjeni utjecaj rizika razlikovati za financijske

The results of qualitative risk analysis can include the following:

- a risk scale according to the impact and probability of occurrence,
- grouping risks according to categories, either their causes or potential reactions to risks,
- a list of risks that require an urgent reaction, and
- monitoring changes in individual risks over time.

The ways of classifying risk are indeed varied and numerous. Classifications primarily depend upon the viewpoint from which the analysis is conducted. Thus, the classification and assessment of risks will differ for financial institutions, developers or, for institucije, voditelje projekata ili npr. državnu administraciju. U ovom je radu prednost dana gledištu koje se u literaturi obično pridjeljuje voditelju projekta, ali se pojedini komercijalni (investitorski) utjecaji ne mogu zanemariti pa su uključeni.

Osnovna podjela rizika u projektima vjetroelektrana je [5]:

– projektni,
– tržišni,
– tehnički,
– politički,
– administrativni.

Utjecaj većine navedenih rizika ovisi o specifičnostima projekta pa je ovdje dana dovoljno općenita analiza. Ipak treba napomenuti da su projektni i tehnički rizici većinom zajednički svim projektima vjetroenergije, budući da ne ovise o političkoj situaciji ili uređenju tržišta. S druge strane, tržišni i politički rizici se bitno razlikuju za pojedine zemlje.

Način podjele nije toliko važan koliko pravilno razmještanje rizika s obzirom na njihovo pojavljivanje u projektu. Projekt vjetroelektrane može se podijeliti u četiri faze [6]:

– pripremna faza,
– faza građenja,
– faza eksploatacije,
– faza razgradnje (*de-commissioning*).

Prihod nastaje samo u fazi eksploatacije. Ostale faze ne donose prihod, već naprotiv, samo troškove i rizike.

### 3.2.1 Rizici u pripremnoj fazi projekta

Planiranje, izrada investicijskog plana, financijska analiza, mjerenje vjetropotencijala je vjerojatno najkompleksniji dio projekta i također dio u kojem se pojavljuje najveći broj rizika. To je logično budući da se radi o prvoj fazi projekta, a rizike je moguće izbjeći samo ako ih se od početka uzme u obzir i analizira.

Rizici u pripremnoj fazi projekta prikazani su u tablici 1.

example, the state administration. In this article, preference is given to the viewpoint which in the literature is generally attributed to the project developer. However, individual commercial (investor) influences cannot be neglected and are therefore included.

The basic risk classifications in wind power plant projects are as follows [5]:

– project,
– market,
– technical,
– political, and
– administrative.

The impact of the majority of the cited risks depends upon the specific characteristics of a project, so that a fairly general analysis is provided here. Nonetheless, it is necessary to mention that project and technical risks are for the most part common to all wind energy projects, since they do not depend upon the political situation or market organization. From the other side, market and political risks vary considerably for individual countries.

The manner of classification is not as important as the correct allocation of risks, taking their occurrence in the project into account. A wind power plant project can be divided into four phases [6]:

– preparatory phase,
– construction phase,
– exploitation phase, and
– decommissioning phase.

Revenue only occurs during the exploitation phase. The other phases do not provide revenue but, on the contrary, only costs and risks.

### 3.2.1 Risks in the preparatory phase of a project

Planning, the devising of an investment plan, financial analysis and the measurement of wind potential probably represent the most complex part of the project and also the part in which the largest number of risks occur. This is logical, since it concerns the first phase of a project, and risks can only be avoided if they are taken into account and analyzed at the beginning.

The risks in the preparatory phase of a project are presented in Table 1.

Tablica 1 – Rizici u pripremnoj fazi projekta
Table 1 – Risks in the preparatory phase of a project

| Etapa / Stage | Aktivnosti / Activities | Uzroci rizika / Causes of risk |
|---|---|---|
| Odabir lokacija za mjerenje / Selection of a location for measurement | Procjena vjetroprilika za potrebe odabira lokacija na kojima će se vršiti mjerenja / Assesssment of the wind conditions for the purposes of selecting locations at which measurements will be performed | – kvaliteta i reference stručnjaka / quality and references of experts |
| | Prostorno-planska dokumentacija / Physical planning documentation | – zaštićenost zemljišta (često u Republici Hrvatskoj) / land protection (frequently in the Republic of Croatia<br>– nemogućnost promjene prostornih planova (VE vjerojatno nije predviđena) / impossibility of changing physical plans (wind energy plant is probably not anticipated) |
| | Imovinsko-pravni odnosi / Property-legal relations | – negativan stav vlasnika prema planiranom projektu / negative attitude of the owners toward the planned project<br>– nerazumni zahtjevi za naknadom / unreasonable demands for compensation<br>– neriješena imovinska situacija / unresolved property situation |
| | Procjena elektroenergetskih prilika u mreži / Assessment of electrical energy conditions in the network | – loše stanje mreže / poor network condition<br>– udaljeno mjesto priključka / distant connection point<br>– potreba za nadogradnjom mreže / necessity for upgrading the network |
| | Uspostavljanje odnosa sa lokalnom zajednicom / Establishment of relations with the local community | – protivljenje lokalne zajednice / opposition from the local community<br>– troškovi zbog dobivanja suglasnosti / costs due to obtaining approvals |
| | Ekološka pitanja / Ecological question | – postojanje zaštićene flore i faune / the existence of protected flora and fauna<br>– posebni uvjeti pri gradnji na lokaciji / special conditions for building on the location |
| | Utvrđivanje pristupačnost lokacije / Determination of the accessibility of the location | – nepostojanje putova koji bi zadovoljili potrebe izgradnje VE / the absence of routes that would meet the requirements for the construction of a wind power plant |
| Mjerenje vjetropotencijala / Measurement of wind potential | Mjerenje vjetropotencijala / Measurement of the wind potential | – nekvalitetno mjerenje / poor quality measurements |
| | Analiza mjernih podataka / Analysis of the measured data | – nekvalitetna obrada podataka / poor quality data processin |
| Aktivnosti nakon odabira lokacije, a paralelno s mjerenjem vjetropotencijala / Activity after the selection of the location, parallel with the measurement of the wind potential | Monitoring flore i faune / Monitoring flora and fauna | – može ustanoviti negativan utjecaj vjetroelektrane na floru i faunu / possibility of establishing the negative impact of the wind power plant on flora and fauna |
| | Izmjena prostornih planova / Amendments to physical plans | – nepredvidivo trajanje (minimalno 6 mjeseci) / unpredictable duration (a minimum of 6 months)<br>– troškove snosi investitor / investor bears the costs<br>– loši odnosi s lokalnom samoupravom mogu rezultirati produžavanjem postupka / poor relations with the local self-management can result in the prolongation of the procedure<br>– greške tijekom izmjene / errors during amendment |
| | Istraživanje mogućnosti priključka / Investigation of potential connections | – zahtjevi za financiranjem nadogradnje mreže od strane operatora / requirements for financing the upgrading of the network by the operator |
| | Izrada SUO / Preparation of an environmental impact study | – može ustanoviti negativan utjecaj na okoliš / possibility of determining a negative impact upon the environment |

| | | |
|---|---|---|
| Odabir vjetroagregata (opreme) / Selection of a wind turbine (equipment) | Određivanje parametara vjetroagregata [7] / Determination of the wind turbine parameters [7] | – krivi odabir bilo kojeg od parametara vjetroagregata može upropastiti projekt / incorrect choice of any of the parameters of the wind turbine can devastate the project |
| | Odabir dobavljača / Selection of supplier | – odabir nekvalitetnog dobavljača / the selection of a poor quality supplier |
| Ishođenje lokacijske dozvole / Obtaining a location permit | Izrada idejnog projekta / Preparation of the preliminary design | – uz kvalitetnog projektanta, rizici su minimalni / with a quality project designer, risks are minimal<br>– nužna suradnja idejnog projektanta s izrađivačem SUO / necessary cooperation between the project designer and the author of the environmental impact study |
| | Procjena utjecaja na okoliš / Assessment of environmental impact | – izmjena rasporeda vjetroagregata zbog vizualnog utjecaja na okoliš (uzrokuje izmjene idejnog projekta) / change in the placement of the wind turbines due to the visual impact on the environment (requires changes in the preliminary design)<br>– zahtjevi za dopunjavanjem SUO (dugotrajno) / requirements for amendments to the environmental impact study (long-term) |
| | Rješavanje imovinsko-pravnih pitanja / Resolution of property-legal questions | – nemogućnost dobivanja prava građenja / the impossibility of obtaining building rights<br>– zahtjevi za nerazumnim naknadama / requirements for unreasonable compensations |
| | Podnošenje zahtjeva za izdavanjem lokacijske dozvole / Submitting application for obtaining a location permit | – dugo trajanje postupka (minimalno 2 mjeseca) / long procedure (minimum of 2 months)<br>– zahtjevi za izmjenama idejnog projekta / requirements for amending the preliminary design<br>– odbijanje izdavanja lokacijske dozvole / refusal to grant a location permit |
| Ishođenje građevinske dozvole / Obtaining a building permit | Izrada glavnog projekta / Preparation of the main project | – izmjene projekta ovisno o posebnim uvjetima (HEP, MUP, Hrvatske vode, Hrvatske šume, itd.) / amendments to the project, depending on special conditions (HEP, the Ministry of the Interior, Croatian Waters, Croatian Forests etc.) |

### 3.2.2 Rizici u fazi izgradnje

Ako je pripremna faza napravljena dobro, ovdje ne treba očekivati nikakve posebne rizike u odnosu na bilo koji građevinski projekt. Statistike za EU govore da se vrijeme građenja kopnene vjetroelektrane kreće između pola godine i godinu dana.

Tablica 2 daje rizike projekta u fazi izgradnje.

### 3.2.2 Risks in the construction phase

If the preparatory phase is executed well, no special risks need to be anticipated here in relation to any construction project whatsoever. Statistics for the EU show that the time required for the construction of a wind power plant on land ranges from between a half a year to a year.

Table 2 presents the project risks during the construction phase.

Tablica 2 – Rizici u fazi izgradnje
Table 2 – Risks during the construction phase.

| Etapa / Stage | Aktivnosti / Activities | Uzroci rizika / Causes of risk |
|---|---|---|
| Građevinski radovi / Construction work | Izrada putova i cesta / Construction of routes and roads | – nepredviđeni problemi s terenom / unforeseen problems from the terrain |
| | Izrada temelja / Foundation construction | – greške u izradi temelja mogu biti fatalne / errors in the construction of the foundation can be fatal |
| Montaža agregata / Turbine installation | Doprema opreme / Equipment delivery | – oprema mora dolaziti po JIT (*just in time*) načelu jer inače dolazi do troškova držanja dizalica i ekipe na terenu / equipment must come according to the just in time (JIT) principle because otherwise there are costs for maintaining the cranes and team on the terrain |
| | Montaža / Installation | – montažu radi dobavljač pa on preuzima sve rizike / installation is performed by the supplier, who assumes all the risks |

### 3.2.3 Rizici u fazi eksploatacije

U fazi rada vjetroelektrane javljaju se većinom tehnički i tržišni rizici. Svi rizici u ovoj fazi vezani su za rizike u proizvodnji i isporuci električne energije. Problemi nastaju kada vjetroelektrana ne radi ili kada proizvodnja energije ne ostvaruje zaradu.

Tablica 3 prikazuje rizike vezane uz eksploataciju.

### 3.2.3 Risks in the exploitation phase

In the phase of the operation of a wind power plant, mostly technical and market risks occur. All the risks in this phase are connected with risks in the production and delivery of electrical energy. Problems occur when a wind power plant is not operating or when the production of energy does not create earnings.

Table 3 presents risks connected with exploitation.

Tablica 3 – Rizici u fazi eksploatacije vjetroelektrane
Table 3 – Risks in the exploitation phase of a wind power plant

| Etapa / Stage | Aktivnosti / Activities | Uzroci rizika / Causes of risk |
|---|---|---|
| Eksploatacija / Exploitation | Proizvodnja energije / Energy production | – loše vjetroprilike / poor wind conditions<br>– kvarovi opreme / equipment breakdowns |
| | Sudjelovanje na energetskom tržištu / Participation on the energy market | – smanjenje poticaja (cijene energije) ispod prihvatljive razine / reduction in incentive (energy price) below an acceptable level |

## 3.3 Kvantitativna analiza rizika

Kvantitativna analiza rizika se vrši na rizicima koji su odabrani kvalitativnom analizom kao najznačajniji za projekt. U ovom dijelu postupka detaljno se analiziraju ti rizici i svakom se dodjeljuju numeričke vrijednosti. Kvantitativna analiza koristi tehnike poput Monte Carlo analize ili analize stabla događaja [3].

U matematičkim proračunima, nesigurnosti su predstavljene slučajnim varijablama (varijablama koje poprimaju nepredvidive vrijednosti). Slučajne varijable je moguće odrediti samo vjerojatnostima kojima one poprimaju neku vrijednost. Rizici se

## 3.3 Quantitative risk analysis

Quantitative risk analysis is performed for risks that are selected by qualitative analysis as the most significant for the project. In this part of the procedure, these risks are analyzed in detail and each is assigned a numerical value. Quantitative analysis uses techniques such as Monte Carlo analysis or event tree analysis [3].

In mathematical calculations, uncertainties are represented by random variables (variables that assume unpredictable values). Random variables can only be determined by the probabilities according to which they assume a value. Risks occur precisely pojavljuju upravo zbog nesigurnosti pa je zbog toga veličina nekog rizika povezana s nekoliko slučajnih varijabli. Koristeći tehnike iz teorije vjerojatnosti, moguće je odrediti razdiobu vjerojatnosti nekog rizika, pod uvjetom da su poznate razdiobe vjerojatnosti nesigurnih varijabli koje taj rizik uzrokuju. Eventualne međuodnose spomenutih nesigurnosti također treba uzeti u obzir [8].

Razdiobe vjerojatnosti neke varijable mogu biti različite, ali se u analizi rizika koristi tek ograničen broj najpoznatijih. Naravno, na tržištu se mogu naći skupi i kompleksni modeli koji nude korisniku izbor iz gotovo neograničenog spektra funkcija, no za razumljivu i preglednu analizu dovoljno je poznavati nekoliko osnovnih (Poissonova, eksponencijalna, Gaussova, itd.).

Rizik koji postoji u nekom projektu mjeri se vjerojatnošću pojave neželjenog događaja. Dakle, potrebno je odabrati neželjeni događaj koji će u analizi biti kriterij za procjenu rizičnosti projekta. Matematički gledano, radi se o jednoj varijabli koja će u konačnici predstavljati mjeru rizičnosti. Ta ključna varijabla (kriterijska varijabla) funkcija je pojedinih rizika (relevantnih varijabli) koji su u matematičkom modelu predstavljeni svojim razdiobama vjerojatnosti [9].

Potrebno je izvršiti sumiranje ili agregaciju funkcija vjerojatnosti rizičnih varijabli. Taj postupak je jednostavan ako su funkcije jednake i ako imaju osobinu reproduktivnosti, to jest ako je zbroj dviju ili više funkcija nekog tipa opet funkcija tog istog tipa. To svojstvo imaju normalna, binomna i poissonova razdioba, ali npr. eksponencijalna nema. Budući da je mala vjerojatnost da sve varijable u modelu budu istog tipa, za agregaciju funkcija se koriste kompleksne računalne metode od kojih je najmodernija i u zadnje vrijeme najviše korištena Monte Carlo metoda [9].

Slika 2 prikazuje kvantitativnu analizu rizika kako ju definira standard AS/NZS 4360 u točki 3 [3].

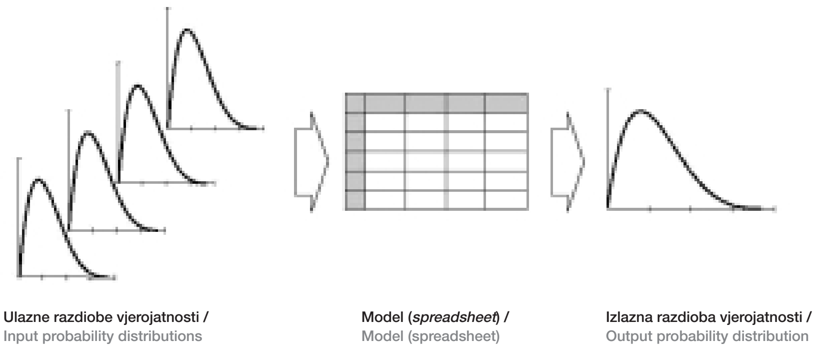
due to uncertainty and therefore the magnitude of a risk is connected with several random variables. Using techniques from the theory of probability, it is possible to determine the probability distribution of a given risk, provided that the probability distributions are known of the uncertain variables that cause this risk. The eventual relationships among these uncertainties should also be taken into consideration [8].

The probability distributions of a variable can vary but only a limited number of the best known are used in risk analysis. Naturally, on the market it is possible to find expensive and complex models that offer the user a selection from nearly an unlimited spectrum of functions. However, for a comprehensible and clear analysis, it is sufficient to be acquainted with several basic ones (Poisson, exponential, Gauss etc.).

The risk that exists in a project is measured by the probability of the occurrence of an undesired event. Thus, it is necessary to select the undesired event that will be the criterion for the assessment of the project risk in the analysis. Viewed mathematically, this concerns one variable that will represent the measure of risk. This key variable (criterion variable) is a function of individual risks (relevant variables) that in a mathematical model are represented by their probability distributions [9].

It is necessary to perform a summation or aggregation of the probability functions of the risk variables. This procedure is simple if the functions are equal and if they have the property of reproducibility, i.e. if the sum of two or more functions of a type is a function of the same type. Normal, binomial and Poisson distributions have this property but, for example, exponential distribution does not. Since there is little likelihood that all the variables in a model would be of the same type, complex computer methods are used for an aggregation, of which the most modern and in recent times the most popular is the  Monte Carlo method [9].

Figure 2 presents the quantitative risk analysis as defined by standard AS/NZS 4360 in Item 3 of [3].




**Slika 2**
Kvantitativna analiza rizika
**Figure 2**
Quantitative risk analysis

### 3.4 Evaluacija rizika

Procjena rizika i predviđanje njihove razdiobe vjerojatnosti nije dovoljna za modeliranje. Rizike je potrebno vrednovati prema nekom kriteriju. Za slučaj projekata kao što su projekti u vjetroenergetici, najčešće se primjenjuje ekonomski kriterij. Dakle, odluke se donose na temelju ekonomske isplativosti predviđenih rezultata. Utjecaj pojedinog rizika potrebno je izraziti preko utjecaja na neku od veličina ekonomskog vrednovanja projekta i zatim analizirati njihovu ovisnost.

Razvojem menadžerskog pristupa financiranju i projektima razvio se cijeli niz metoda financijskog odlučivanja [10] i [11]. Pri odabiru metode za evaluaciju projekta s gledišta analize rizika treba voditi računa o potencijalnim korisnicima modela. Donositelji odluka ne moraju biti i vrlo često nisu stručnjaci za ekonomsku znanost. Tako su u ovom radu odabrane tri temeljne metode financijskog odlučivanja.

Bit ocjene rentabilnosti (ekonomska ocjena za investitora) jest u procjeni povećava li se materijalna osnova projekta ili smanjuje kada se uzme u obzir cijeli vijek projekta. U dinamičkom pristupu ocjeni ekonomskog doprinosa projekta korištene su sljedeće metode [10] i [11]:

– metoda razdoblja povrata investicijskih ulaganja,
– metode diskontiranih tokova novca, i to nakon oporezivanja:
  · interna stopa povrata i
  · čista sadašnja vrijednost.

### 3.4 Risk evaluation

The assessment of risks and the prediction of their probability distribution are not sufficient for modeling. Risks must be assessed according to some criterion. In the case of projects such as wind energy plants, economic criteria are most commonly used. Decisions are made on the basis of the profitability of the forecast results. The impact of an individual risk must be expressed through the impact upon some of the values of the economic assessment of the project and then their dependence should be analyzed.

Through the development of a managerial approach to financing and projects, an entire series of methods of financial decision making have been developed [10] and [11]. In selecting methods for the evaluation of a project from the viewpoint of risk analysis, it is necessary to take account of the potential users of the model. Decision makers do not have to be and very often are not experts in economic science. Therefore, three fundamental methods have been selected in this article for financial decision making.

The essence of profitability assessment (economic assessment for the investor) is to assess whether there is an increase or decrease in the material basis of a project when the entire lifetime of the project is taken into account. In the dynamic approach to the assessment of the economic contribution of a project, the following methods are used [10] and [11]:

– the payback period method,
– the discounted cash flows method, after taxation:
  · the internal rate of return, and
  · the net present value.

# 4 MODEL ZA KVANTITATIVNU ANALIZU RIZIKA

Model za analizu rizika projekata vjetroelektrana u Republici Hrvatskoj izrađen je u Microsoft Excelu. Odabir programskog paketa uvjetovan je njegovom rasprostranjenošću. Model je namijenjen donositeljima odluka i voditeljima projekata te je stoga ključno da bude što jednostavniji za korištenje. Excel je vrlo raširen i korišten programski alat i većina je ljudi dobro upoznata s njegovim osnovnim funkcijama i mogućnostima. Korištenje ovog modela ne zahtijeva napredno korištenje Excela, iako je preporučljivo upoznati se s elementima programskog alata koji su opisani u daljnjem tekstu. Za detaljno prilagođavanje i mijenjanje modela ipak je nužno minimalno obrazovanje u vidu nekog od dostupnih tečajeva za napredno korištenje Excela u trajanju od nekoliko tjedana.

### 4.1 Programski dodaci korišteni pri razvoju modela

Pri izradi modela korišteni su programski dodaci (*add-in*) koji su dio potpune instalacije programskog paketa Excel. Također je izvršena nadogradnja pomoću *shareware* programskih dodataka i jednog *emailware*. Svi navedeni programski dodatci dostupni su na Internet stranicama vezanim uz Excel.

*Add-in* je program koji dodaje proizvoljne funkcije i proširuje mogućnosti Excela. *Add-in* sadrži set funkcija i oruđa koji omogućuju skraćivanje koraka pri razvoju kompleksnih analiza. Excel podržava tri tipa dodataka: Excel *add-in*, COM (*Component Object Model*) *add-in* i automatski *add-in*. Model razvijen u ovom radu podrazumijeva ugradnju Excel i COM dodataka. Excel *add-in* ima ekstenziju *.*xla*, COM *add-in* ima ekstenziju *.*dll* ili *.*exe*. Za ispravno funkcioniranje predmetnog modela potrebno je instalaciju Excel programa upotpuniti sljedećim dodacima:

– *Analysis ToolPak add-in* je paket financijskih, statističkih i inženjerskih funkcija koji je dio potpune instalacije Excela,
– VBA *add-in* omogućuje izradu vlastitih *macro* potprograma u *Visual Basic* programskom jeziku koji se ponašaju kao obične Excel funkcije. Ovaj dodatak nije dio standardne instalacije Excela pa ga je potrebno dodati,
– *Solver add-in* računa rješenja u što-ako analizi. Također nije dio standardne instalacije Excela pa ga je potrebno dodati,
– *Microsoft Office Web Components* (OWC) je kolekcija COM *add-in* dodataka koji omogućuju objavljivanje Excel stranica i tablica na internetu [12],

# 4 MODEL FOR QUANTITATIVE RISK ASSESSMENT

A model for the analysis of the risk of a wind power plant projects in the Republic of Croatia has been prepared in Microsoft Excel. The selection of the program package was determined by its popularity. The model is intended for decision makers and project developers. Therefore, it is crucial for it to be as simple as possible to use. Excel is a very popular software tool and the majority of people are well acquainted with its basic functions and possibilities. The use of this model does not require the use of advanced Excel functions, although becoming acquainted with the elements of the software tool that are described later in the text is recommended. For the detailed adaptation and modification of the model, minimum training is required such as that available from courses in the advanced use of Excel, which last for several weeks.

### 4.1 Software add-ins used in the development of the model

In developing the model, software add-ins were used that are part of the complete Excel package. Furthermore, upgrading was performed using shareware software add-ins and one emailware. All the cited software add-ins are available on the Web pages connected with Excel.

An add-in is a program that adds arbitrary functions and expands the possibilities of Excel. An add-in contains a set of functions and tools that makes shortcuts possible in the development of complex analyses. Excel supports three types of add-ins: Excel add-in, the Component Object Model (COM) add-in and the automatic add-in. The model referred to in this article presumes the installation of Excel and the COM add-ins. Excel add-ins have the extension *.xla, COM add-ins have the extension *.dll or *.exe. For the correct function of this model, it is necessary to install the Excel program with the following add-ins:

– The Analysis ToolPak add-in is a package of financial, statistical and engineering functions that is a part of full Excel installation,
– The VBA add-in makes it possible to devise your own macro subprograms in the Visual Basic programming language, which behave like ordinary Excel functions. This add-in is not part of the standard Excel installation and must be added,
– The Solver add-in calculates solutions in what-if analysis. It is also not part of the standard Excel installation and must be added,
– Microsoft Office Web Components (OWC) are a collection of Component Object Model (COM) add-ins that facilitates the publication of Excel pages and tables on the Internet [12],

- *SimulAr add-in* je dodatak koji omogućuje Monte Carlo analizu [13].

### 4.2 Opis modela

Model analize rizika za projekte vjetroelektrana u Republici Hrvatskoj koristi Monte Carlo analizu kao temeljni postupak pri proračunu gustoće vjerojatnosti pojedinih varijabli. Ova metoda podrazumijeva dodjeljivanje razdioba vjerojatnosti varijablama modela koje predstavljaju rizike te zatim generiranje slučajnih brojeva u okviru odabranih razdioba vjerojatnosti kako bi se simulirali budući događaji.

Koraci pri simuliranju su sljedeći:

- definiranje ulaznih varijabli,
- definiranje izlaznih (promatranih) varijabli,
- unošenje korelacijskih koeficijenata (proizvoljan korak),
- simuliranje,
- prikaz rezultata.

Model je testiran na primjeru 20 vjetroagregata jedinične snage 1 MW sa životnim vijekom od 25 godina.

### 4.3 Definiranje ulaznih varijabli

Ulazne varijable modela su rizici za koje se vjeruje da će u budućnosti imati utjecaj na projekt. Svi rizici su pretvoreni u novčane jedinice kako bi se njihov utjecaj mogao prikazati promjenama financijskih pokazatelja projekta. Svakom od navedenih rizika pridružena je razdioba vjerojatnosti. Model nudi mogućnost za unošenje 500 ulaznih varijabli i pridruživanje 20 različitih razdioba vjerojatnosti.

Raspoložive razdiobe vjerojatnosti su: normalna, trokutasta, uniformna, beta, kvadratna, lognormalna, lognormalna kvadratna, gama, logistička, eksponencijalna, studentova, usporedna, weibullova, rayleigheva, binomna, negativna binomna, geometrijska, poissonova, diskretna i diskretno uniformna.

Ulazne varijable modela su kako slijedi:

- godišnja proizvodnja,
- mjerenje vjetropotencijala,
- promjena prostornog plana,
- geodetska snimka,
- lokacijska dozvola,
- građevinski radovi,
- priključak na mrežu,
- priključna TS.

- The SimulAr add-in is for Monte Carlo analysis [13].

### 4.2 Model description

The risk analysis model for the wind power plant projects in the Republic of Croatia uses Monte Carlo analysis as the basic procedure in the calculation of the probability density of individual variables. This method implies assigning probability distributions to the model variables, which represent risks, followed by the generation of random numbers within the framework of the selected probability distributions in order to simulate future events.

The steps in simulation are as follows:

- the definition of the input variables,
- the definition of the output (observed) variables,
- the entry of correlation coefficients (arbitrary step),
- simulation, and
- the presentation of the results.

The model has been tested on a sample of 20 wind turbines, each with a 1 MW power rating and a lifetime of 25 years.

### 4.3 Definition of input variables

The input variables of the model are risks that are believed to have a future impact on the project. All risks are transformed into monetary units in order for their impact to be presented as changes in the financial indices of the project. Each of the cited risks is associated with probability distribution. The model offers the option of entering 500 input variables and 20 different associated probability distributions.

The available probability distributions are as follows: normal, triangular, uniform, beta, square, log-normal, log-normal square, gamma, logistical, exponential, student, comparative, Weibull, Rayleigh, binomial, negative binomial, geometric, Poisson, discrete and discrete uniform.

The input variables of the model are as follows:

- annual production,
- measured wind potential,
- change in the physical plan,
- geodetic image,
- location permit,
- construction work,
- connection to the network, and
- connection substation.

Kao primjer matematičkog prikazivanja rizika poslužit će varijabla godišnja proizvodnja po jedinici (MWh) koja se kasnije množi s cijenom MWh i brojem instaliranih agregata kako bi u proračunu bila izražena kroz novčane jedinice. Ostale ulazne varijable modelirane su na isti način.

Za godišnju proizvodnju odabrani su sljedeći parametri: normalna razdioba, s intervalom od 1 900 MWh do 2 600 MWh, srednja vrijednost $\mu$ = 2 250, standardna devijacija $\sigma$ = 250.

Pretpostavljena je godišnja proizvodnja između 1 900 MWh i 2 600 MWh, što su odlike prilično dobre lokacije. Svjetska praksa računa lokaciju s iznad 2 000 sati nazivnog rada kao vrlo dobru, ali ovdje treba uzeti u obzir povoljne i sigurne uvjete otkupa energije koji u inozemstvu omogućavaju isplativost i lošijih lokacija. Za hrvatske prilike ovakva lokacija je prosjek ispod kojega vjerojatno nije isplativo investirati.

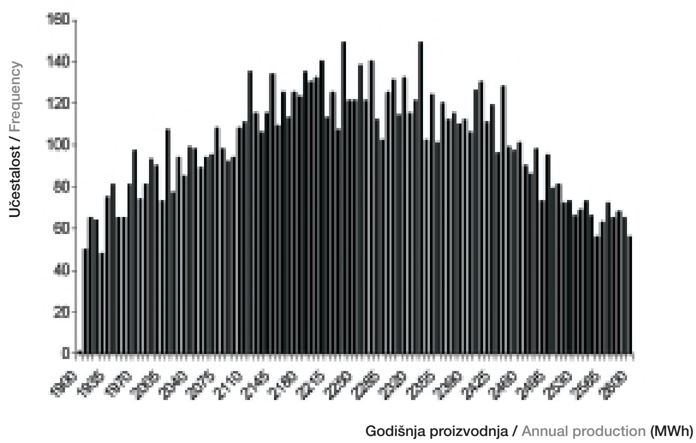
Slika 3 prikazuje razdiobu vjerojatnosti varijable godišnja proizvodnja prema primijenjenom modelu na temelju 10 000 pokušaja. Ovdje je bitno napomenuti da su na apscisi prikazane ključne frekventne točke oko kojih se grupiraju rezultati, a ne stvarne vrijednosti iteracijskih koraka. Stoga vrijednost prikazana na apscisi možda u stvarnosti nije niti jednom bila dobivena.

The annual production per unit (MWh) variable will serve as an example of a mathematical demonstration of risk, which will later be multiplied by the price per MWh and the number of installed wind turbines, so that the calculation will be expressed through monetary units. The remaining input variables are modeled in the same manner.

For annual production, the following parameters have been selected: the normal distribution, period with an interval of 1 900 MWh to 2 600 MWh, mean value $\mu$ = 2 250, standard deviation $\sigma$ = 250.

Annual production of between 1 900 MWh and 2 600 MWh is assumed, which characterizes a fairly good location. In world practice, a location with over 2 000 hours of nominal operation is considered to be very good. However, it is necessary to take favorable and secure conditions into account in the buying up of energy in other countries, although even poorer locations may be profitable. For the Croatian situation, such a location is the average, below which investment is probably not worthwhile.

Figure 3 presents the probability distribution of annual production variable according to the applied model on the basis of 10 000 iterations. It is necessary to mention here that the key frequency points are shown on the abscissa, around which the results are grouped, and not the actual values of the iterative steps. Therefore, the value shown on the abscissa may never have been obtained in reality.




**Slika 3**
Razdioba vjerojatnosti varijable godišnja proizvodnja
**Figure 3**
Probability distribution of annual production variable

### 4.4 Definiranje izlaznih varijabli

Izlazne varijable su rezultat simulacije u kojoj se 10 000 puta odabiru slučajne vrijednosti ulaznih varijabli te se prema modelu proračunavaju izlazne varijable. Rezultati simulacija služe da bi se Monte Carlo metodom odredile razdiobe vjerojatnosti izlaznih varijabli. Odabrane su sljedeće izlazne varijable:

- ukupna investicija (*UI*),
- razdoblje povrata investicije (*RPI*),
- čista sadašnja vrijednost (*ČSV*),
- interna stopa rentabilnosti (*ISR*).

Ukupna investicija dobiva se zbrajanjem svih troškova. Ovo zapravo nije kriterijska varijabla koja bi služila za evaluaciju projekta, ali je u svakom slučaju interesantna pa je zbog toga i razmotrena.

Čista sadašnja vrijednost (*ČSV*) se računa pomoću Excel ugrađene funkcije *npv*, a na temelju novčanih tokova nakon 25 godina rada elektrane. Pretpostavljena diskontna stopa *d* je 10 %. Korištena formula je:

### 4.4 The definition of output variables

Output variables are the result of simulation in which the random values of input variables are selected 10 000 times and the output variables are calculated according to the model. Simulation results serve for the determination of the probability distributions of output variables using the Monte Carlo method. The following output variables have been chosen:

- total investment (*TI*),
- payback period (*PP*),
- net present value (*NPV*),
- internal rate of return (*IRR*).

Total investment is obtained from the sum of all the costs. This is actually not a criterion variable for the eventual project but in any case is interesting and therefore it is considered.

The net present value (*NPV*) is calculated using the Excel npv function, on the basis of cash flows after the power plant has been in operation for 25 years. The assumed discount rate, *d*, is 10 %. The formula used is as follows:

$$ČSV = \sum_{t=1}^{n} \frac{nt}{(1+d)^t}, \qquad NPV = \sum_{t=1}^{n} \frac{cf}{(1+d)^t}, \qquad (1)$$

gdje su:

- $ČSV$ – čista sadašnja vrijednost,
- $nt$ – novčani tokovi za period efektuiranja,
- $d$ – diskontna stopa (u modelu 10 %).

Interna stopa rentabilnosti (*ISR*) računa se pomoću Excel ugrađene funkcije *irr*. Excel računa *ISR* iterativnim postupkom traženja stope povrata za nultu vrijednost čiste sadašnje vrijednosti. Proračun se vrši sve dok odstupanje nije unutar 0,000 01 %, što je svakako dovoljno precizno za potrebe ovog modela.

Razdoblje povrata investicije (*RPI*) računa se kombinacijom ugrađenih funkcija *lookup* i *if*. Model dopušta proglašavanje bilo koje varijable izlaznom varijablom.

where:

- $NPV$ – net present value,
- $cf$ – cash flows for the period of effectuation,
- $d$ – discount rate (10 % in the model).

The internal rate of return (*IRR*) is calculated using the Excel irr function. Excel calculates the *IRR* using an iterative procedure for seeking the rate of return for the zero value of the net present value. Calculation is performed until the deviation is within 0,000 01 %, which is certainly sufficiently precise for the purposes of this model.

The payback period (*PP*) is calculated through a combination of the lookup functions and if functions. The model permits the designation of any variable as the output variable.

### 4.5 Određivanje korelacija

Ponekad su ulazne varijable međusobno ovisne pa je te ovisnosti potrebno unijeti u model, potrebno je odrediti matricu korelacija. Predmetni model dopušta određivanje korelacijskog koeficijenta između –1 i 1 za bilo koje dvije varijable. Ako je korelacijski koeficijent 1 (savršeno pozitivan odnos), dvije se varijable kreću zajedno, što znači

### 4.5 Determination of correlations

Sometimes input variables are mutually dependent and this dependence must be entered into the model. It is necessary to determine the correlation matrix. This model permits the determination of the correlation coefficient between –1 and 1 for any two variables. If the correlation coefficient is 1 (perfect positive correlation), the two variables move togethda ako se jedna poveća za 10 %, isto će učiniti i druga. Ako je korelacijski koeficijent –1 (savršeno negativan odnos), varijable se kreću suprotno, što znači da ako se jedna poveća za 10 %, druga će se smanjiti za isti postotak. Svi koeficijenti koji su između –1 i 1 daju adekvatne korelacije.

U modelu su korelirana dva para varijabli:

- godišnja proizvodnja i mjerenje vjetropotencijala stavljeni su u korelaciju s koeficijentom 0,8. Dakle, matematički gledano, ako se troškovi mjerenja vjetropotencijala povećaju 10 %, godišnja proizvodnja će porasti 8 %. Naravno, ovdje se radi o varijablama, a ne o stvarnoj situaciji. U stvarnosti će veće ulaganje u mjerenje vjetropotencijala rezultirati točnijim određivanjem najpovoljnijeg broja i veličine vjetroagregata, što znači manjom vjerojatnošću krive procjene proizvodnje,
- geodetska snimka i građevinski radovi korelirani su s koeficijentom 0,5. Do veze između ovih rizika dolazi zbog terenskih radova. Ako je geodetska snimka skupa, lokacija je velika ili nepristupačna, što znači da se mogu očekivati povećani troškovi izgradnje.

## 5 REZULTATI (IZVJEŠĆE O ANALIZI RIZIKA)

### 5.1 Ukupna investicija

Slika 4 prikazuje razdiobu vjerojatnosti varijable ukupna investicija.

er, which means that if one is increased by 10 %, the other will be also. If the correlation coefficient is –1 (perfect negative correlation), the variables move in the opposite directions, which means that if one is increased by 10 %, the other will be decreased by 10 %. All the coefficients that are between –1 and 1 yield adequate correlations.

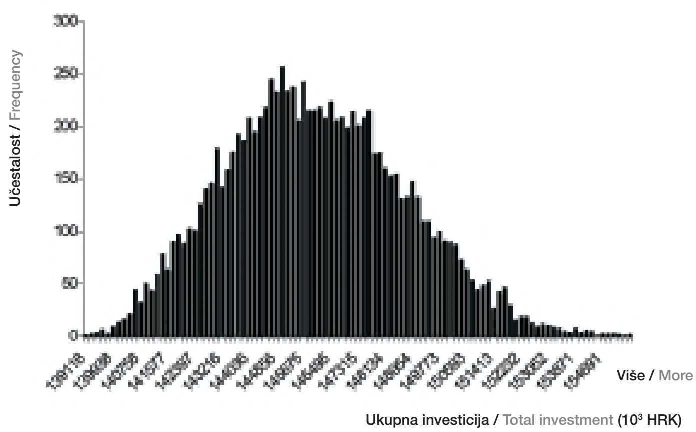
Two pairs of variables are correlated in the model, as follows:

- annual production and wind potential measurement are correlated with the coefficient 0,8. Thus, mathematically speaking, if the costs of measuring wind potential increase by 10 %, the annual production will increase by 8 %. Naturally, this concerns variables and not the actual situation. In reality, greater investments in the measurement of wind potential will result in the more precise determination of the most suitable number and size of wind turbines, which means a lower likelihood of an incorrect production estimate,
- the geodetic image and construction work are correlated with the coefficient of 0,5. The connection between these risks occurs due to field work. If a geodetic image is expensive, the location is large or inaccessible, which means that increased construction costs can be expected.

## 5 RESULTS (RISK ANALYSIS REPORT)

### 5.1 Total investment

Figure 4 presents the probability distribution of the total investment variable.




**Slika 4** Razdioba vjerojatnosti varijable ukupna investicija
**Figure 4** Probability distribution of the total investment variable

Iz razdiobe vjerojatnosti moguće je očitati sljedeće podatke (tablica 4):

The following data can be read from the probability distribution (Table 4):

Tablica 4 – Ključni podaci razdiobe vjerojatnosti varijable ukupna investicija
Table 4 – Key data of the probability distribution of the total investment variable

| Podatak / Data | Vrijednost / Value ($10^3$ HRK) |
|---|---|
| Minimum / Minimum | 139 118 |
| Srednja vrijednost / Mean value | 145 944 |
| Maksimum / Maximum | 155 510 |
| Standardna devijacija / Standard deviation | 2 694 |
| Raspon / Range | 16 392 |

Ukupna investicija je varijabla s normalnom razdiobom vjerojatnosti i parametrima: srednja vrijednost $\mu$ = 145,94 milijuna kuna, standardna devijacija $\sigma$ = 2,69 milijuna kuna. Rasipanje ove varijable je malo, a uzrok tome je pretežiti udio troška opreme koji je fiksan u ukupnoj investiciji.

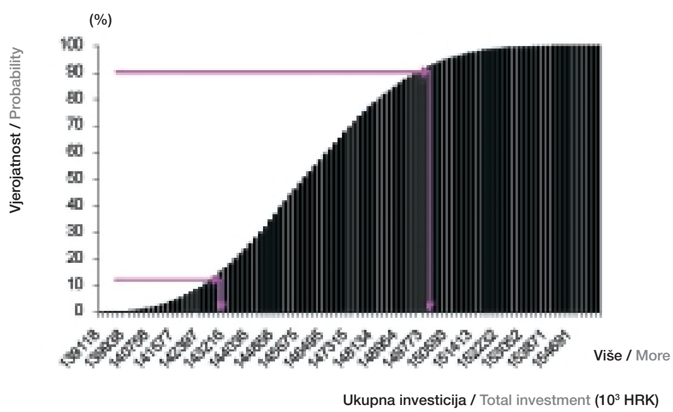
Vjerojatnost se računa integriranjem po funkciji gustoće vjerojatnosti, to jest integral za bilo koju vrijednost daje vjerojatnost da konačna vrijednost projekta bude manja od zadane. Ovaj je podatak ključan za analizu rizika. Rezultirajuća funkcija je kumulativna funkcija vjerojatnosti varijable (u ovom slučaju vrijednosti projekta) [14].

Slika 5 prikazuje kumulativnu razdiobu vjerojatnosti varijable ukupna investicija.

The total investment is the variable with the normal probability distribution and is parameterized: mean value $\mu$ = 145,94 million kunas, standard deviation is $\sigma$ = 2,69 million kunas. The variable dispersion is low, due to the predominant share of equipment costs, which is fixed in total investment.

Probability is calculated by the integration of the probability density function, i.e. the integral for any value yields the probability that the finite value of the project will be lower than the given value. This fact is crucial for risk analysis. The resulting function is the cumulative function of the variable probability (in this case the project value) [14].

Figure 5 presents the cumulative probability distribution of the of the total investment variable.




**Slika 5**
Kumulativna razdioba vjerojatnosti varijable ukupna investicija
**Figure 5**
Cumulative probability distribution of the total investment variable

Uobičajeni podatak koji za analizu rizika daje kumulativna razdioba vjerojatnosti je 80 %-tna granica pouzdanosti [14] koja je u ovom slučaju: 142 560 000 kuna < ukupna investicija < 149 609 000 kuna.

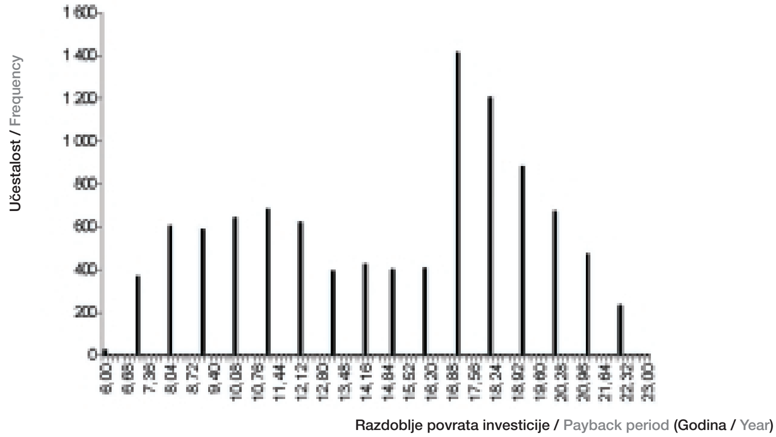
The customary value yielded by cumulative probability distribution in risk analysis is the 80% confidence limit [14] which in this case is: 142 560 000 kunas < total investment < 149 609 000 kunas.

## 5.2 Razdoblje povrata investicije

Slika 6 prikazuje razdiobu vjerojatnosti varijable razdoblje povrata investicije.

## 5.2 The payback period

Figure 6 presents the probability distribution of the payback period variable.




**Slika 6** Razdioba vjerojatnosti varijable razdoblje povrata investicije

**Figure 6** Probability distribution of the payback period variable

Iz razdiobe vjerojatnosti moguće je očitati sljedeće podatke (tablica 5):

From the probability distribution, it is possible to obtain the following data (Table 5):

Tablica 5 – Ključni podaci razdiobe vjerojatnosti varijable razdoblje povrata investicije
Table 5 – Key data of the probability distribution of the payback period variable

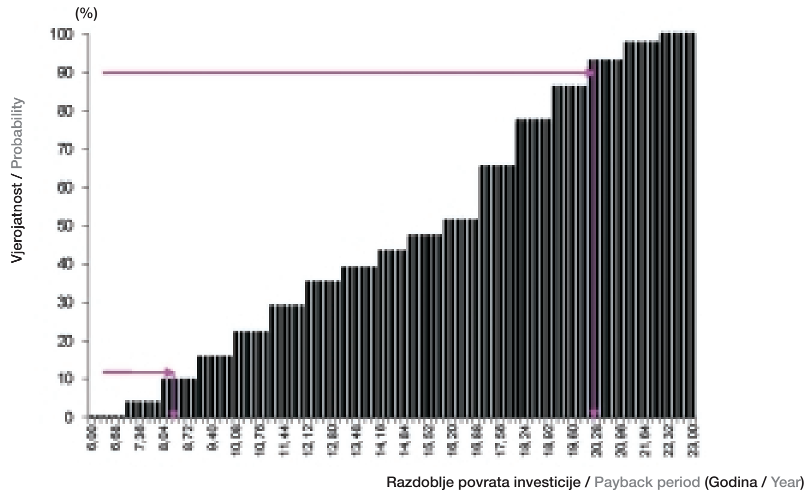
| Podatak / Data | Vrijednost / Value (Godina/Year) |
|---|---|
| Minimum / Minimum | 6 |
| Srednja vrijednost / Mean value | 14,83 |
| Maksimum / Maximum | 23 |
| Standardna devijacija / Standard deviation | 4,31 |
| Raspon / Range | 17 |

Razdioba vjerojatnosti razdoblja povrata investicije ne odgovara nekoj poznatoj funkciji. Štoviše, razdoblje povrata investicije je diskretna varijabla koja poprima 18 vrijednosti u periodu od 17 godina. To je logično budući da je model postavljen tako da period povrata investicije uvijek bude cjelobrojna varijabla izražena u godinama. Iz numeričkih podataka može se vidjeti da je vrijednost 23 godine u 10 000 pokušaja dobivena samo 2 puta (0,02 %), što se ne vidi iz grafičkog prikaza.

Slika 7 prikazuje kumulativnu razdiobu vjerojatnosti varijable razdoblje povrata investicije.

The probability distribution of payback period does not correspond to some known function. Moreover, the payback period is a discrete variable that acquires 18 values within a period of 17 years. This is logical, since the model is set up in such a manner that the payback period is always a integer variable expressed in years. From the numerical data, it can be seen that the value at 23 years in 10 000 iterations is obtained only two times (0,02 %), which is not seen from the graphic presentation.

Figure 7 presents the cumulative probability distribution of the payback period variable.




**Slika 7**
Kumulativna razdioba vjerojatnosti varijable razdoblje povrata investicije
**Figure 7**
Cumulative probability distribution of the payback period variable

80 %-tna granica pouzdanosti je: 8 godina < razdoblje povrata investicije < 20 godina. Dakle, s 80 %-tnom pouzdanošću se može utvrditi da će se period povrata investicije kretati u tom intervalu. To i nije loše ako se uzme u obzir srednja vrijednost razdiobe vjerojatnosti koja je oko 15 godina, ali ne predstavlja mamac za ulagače.

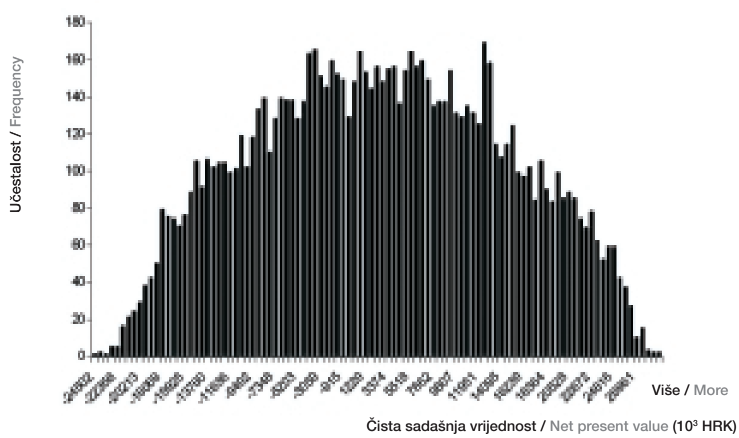
The 80 % confidence limit is: 8 years < payback period < 20 years. Thus, with 80 % confidence, it is possible to determine that the payback period will be within that interval. This is not bad if the mean value of the probability distribution is taken into account, which is approximately 15 years and does not represent a lure to investors.

## 5.3 Čista sadašnja vrijednost

Slika 8 prikazuje razdiobu vjerojatnosti varijable čista sadašnja vrijednost.

## 5.3 Net present value

Figure 8 presents the probability distribution of the net present value variable.




**Slika 8**
Razdioba vjerojatnosti varijable čista sadašnja vrijednost
**Figure 8**
Probability distribution of the net present value variable

Iz razdiobe vjerojatnosti moguće je očitati sljedeće podatke (tablica 6):

From the probability distribution, it is possible to obtain the following data (Table 6):

Tablica 6 – Ključni podaci razdiobe vjerojatnosti varijable čista sadašnja vrijednost
Table 6 – Key data for the probability distribution of the net present value variable

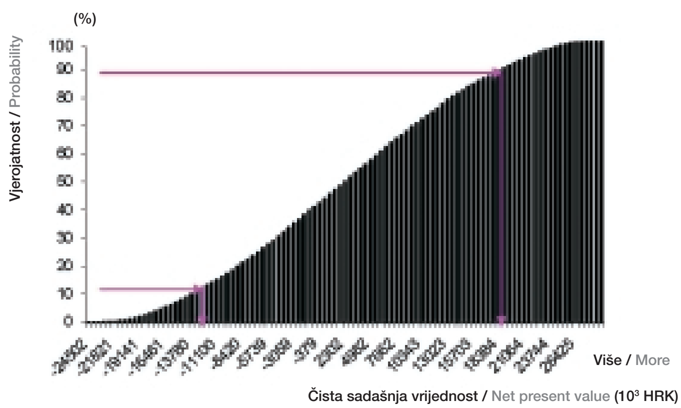
| Podatak / Data | Vrijednost / Value ($10^3$ HRK) |
|---|---|
| Minimum / Minimum | – 24 501 |
| Srednja vrijednost / Mean value | 2 324 |
| Maksimum / Maximum | 29 105 |
| Standardna devijacija / Standard deviation | 11 744 |
| Raspon / Range | 53 606 |

Čista sadašnja vrijednost je varijabla s normalnom razdiobom vjerojatnosti i parametrima srednja vrijednost $\mu$ = 2,32 milijuna kuna, standardna devijacija $\sigma$ = 11,74 milijuna kuna. Rasipanje je znatno veće nego kod npr. ukupne investicije, što je vidljivo i iz grafova.

Slika 9 prikazuje kumulativnu razdiobu vjerojatnosti varijable čista sadašnja vrijednost.

The net present value is a variable with normal probability distribution and parameters with a mean value of $\mu$ = 2,32 million kunas, standard deviation $\sigma$ = 11,74 million kunas. Dispersion is significantly greater than in, for example, total investment, which is also evident from the graphs.

Figure 9 presents the cumulative probability distribution of the net present value variable.




**Slika 9**
Kumulativna razdioba vjerojatnosti varijable čista sadašnja vrijednost
**Figure 9**
Cumulative probability distribution of the net present value variable

80 %-tna granica pouzdanosti je: –13 780 460 kuna < čista sadašnja vrijednost < 18 919 730 kuna. Dakle, s 80 %-tnom pouzdanošću se ne može utvrditi da će čista sadašnja vrijednost biti pozitivna. Kriterij procjene projekta na temelju čiste sadašnje vrijednosti traži da ona bude pozitivna, što se po kumulativnoj krivulji dešava na iznosu vjerojatnosti od 43 %. To znači da je vjerojatnost uspješnog projekta 57 %.

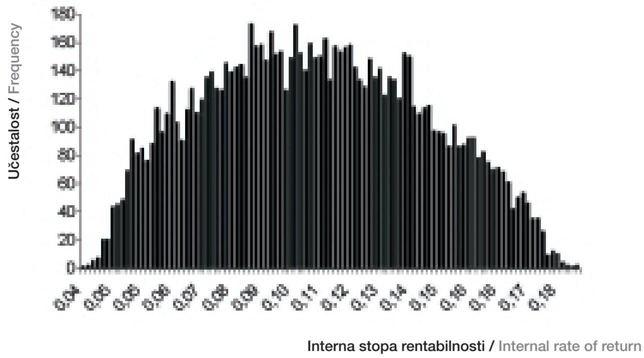
The 80 % confidence limit is: –13 780 460 kunas < net present value < 18 919 730 kunas. Thus, it is not possible to determine whether the net present value will be positive with 80 % confidence. The criterion for the assessment of the project based upon net present value requires it to be positive, which according to the cumulative curve occurs at a probability of 43 %. This means that the probability of the success of the project is 57 %.

## 5.4 Interna stopa rentabilnosti

Slika 10 prikazuje razdiobu vjerojatnosti varijable interna stopa rentabilnosti.

## 5.4 Internal rate of return

Figure 10 presents the probability distribution of the internal rate of return variable




**Slika 10**
Razdioba vjerojatnosti varijable interna stopa rentabilnosti
**Figure 10**
Probability distribution of the internal rate of return variable

Iz razdiobe vjerojatnosti moguće je očitati sljedeće podatke (tablica 7):

From the probability distribution, it is possible to obtain the following data (Table 7):

Tablica 7 – Ključni podaci razdiobe vjerojatnosti varijable interna stopa rentabilnosti
Table 7 – Key data on the probability distribution of the internal rate of return variable

| Podatak / Data | Vrijednost / Value |
|---|---|
| Minimum / Minimum | 0,036 122 265 |
| Srednja vrijednost / Mean value | 0,107 410 979 |
| Maksimum / Maximum | 0,189 512 628 |
| Standardna devijacija / Standard deviation | 0,033 570 573 |
| Raspon / Range | 0,153 390 363 |

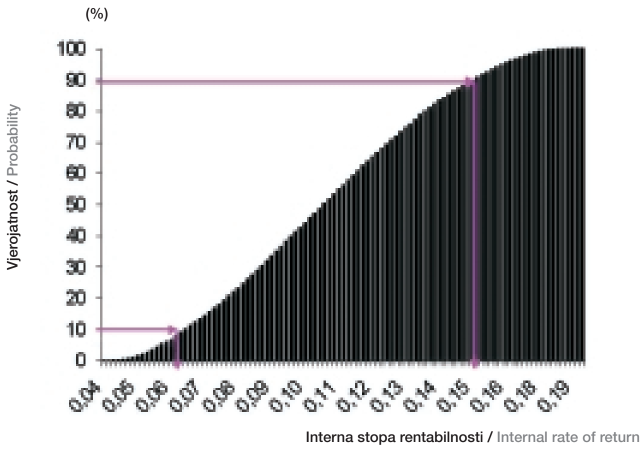
Interna stopa rentabilnosti je varijabla s normalnom razdiobom vjerojatnosti i parametrima srednja vrijednost $\mu$ = 10,7 %, standardna devijacija $\sigma$ = 3,35 %.

Kumulativna razdioba vjerojatnosti interne stope rentabilnosti prikazana je na slici 11.

The internal rate of return is a variable with normal probability distribution and parameters with a mean value of $\mu$ = 10,7 %, standard deviation of $\sigma$ = 3,35 %.

The cumulative probability distribution of the internal rate of return variable is presented in Figure 11.

**Slika 11**
Kumulativna razdioba vjerojatnosti varijable interna stope rentabilnosti
**Figure 11**
Cumulative probability distribution of the internal rate of return variable




80 %-tna granica pouzdanosti je: 0,06 < interna stopa rentabilnosti < 0,15. Kriterij procjene projekta temeljem interne stope rentabilnosti zahtijeva da interna stopa rentabilnosti bude veća ili jednaka zadanoj diskontnoj stopi (10 %). Taj je kriterij zadovoljen vjerojatnošću od 49 %, što je blizu vrijednosti dobivene za čistu sadašnju vrijednost (43 %).

The 80 % confidence limit is: 0,06 < internal rate of return < 0,15. The criterion for the assessment of the project based upon the internal rate of return requires that the internal rate of return is greater than or equal to the given discount rate (10 %). This criterion is met with a probability of 49 %, which is close to the value obtained for the net present value (43 %).

# 6 ZAKLJUČAK

Projekt izgradnje vjetroelektrane, od traženja lokacije do proizvodnje je višegodišnji, složeni projekt tijekom kojega su sve zainteresirane strane izložene brojnim rizicima od kojih su neki dovoljno značajni da mogu upropastiti projekt. Analiza rizika je potrebna da bi investitor i voditelj projekta što bolje predvidjeli i izbjegli buduće probleme. S druge strane, institucije koje daju kredite za projekte vjetroelektrana i same vrše analizu rizika prema modernim načelima pa dobra priprema može značiti razliku između dobivanja i nedobivanja kredita.

U radu su uspoređene različite metode analize rizika i navedeni nedostatci svake pojedine. Numeričko modeliranje rizika je suvremena metoda analize rizika koja daje lako mjerljive i usporedive podatke, budući da svaki rizik pretvara u funkciju razdiobe vjerojatnosti mogućih ishoda. Rezultat analize je graf koji predstavlja egzaktnu informaciju o rizičnosti projekta. Najosjetljiviji dio modela je određivanje razdioba vjerojatnosti ulaznih varijabli. U ovom radu je to učinjeno uz korištenje postojećih (svjetskih i hrvatskih) iskustava u projektima vjetroenergetike.

Na temelju provedene analize rizika može se zaključiti sljedeće:

- projekti vjetroelektrana u Hrvatskoj su isplativi, ali uz umjerene financijske pokazatelje. Radi se o relativno sigurnoj investiciji koja se isplaćuje nakon 12 do 15 godina,
- najutjecajniji rizici su vezani uz mjerenje vjetropotencijala, budući da o tome ovisi proizvodnja (zarada) vjetroelektrane. Mjerenje vjetropotencijala je osnovni pokazatelj isplativosti projekta pa ga i financijske institucije vrlo ozbiljno shvaćaju, tako da o kvaliteti mjerenja ovisi dobivanje kredita za izgradnju vjetroelektrane,
- u Hrvatskoj su prilike još uvijek nesigurne s aspekta administrativnih rizika (dozvole, suglasnosti), što može znatno povećati vrijeme potrebno za pripremne radove (prije početka gradnje). Ova situacija će se u budućnosti poboljšavati, ali to nažalost neće biti dovoljno brzo za projekte koji su danas u fazi mjerenja.

Iako je referentni slučaj u modelu projekt vjetroelektrane u hrvatskim uvjetima, moguće ga je prilagoditi za bilo koje tržište. Glavne razlike između Hrvatske i zemalja Europske unije očituju se u rizicima vezanim uz administrativne procedure, model poticanja obnovljivih izvora energije i imovinsko-pravna pitanja. Promjene u izgledu funkcija razdioba vjerojatnosti pojedinih

# 6 CONCLUSION

The construction of a wind power plant is a complex project that requires many years, from the seeking of the location to production, during which time all the interested parties are exposed to numerous risks, including some with potentially devastating consequences. Risk analysis is necessary in order for the investor and developer to anticipate and avoid future problems to the greatest possible extent. On the other side, institutions that provide loans for wind power plant projects perform risk analysis according to modern principles, so that good preparation can signify the difference between obtaining and not obtaining a loan.

In the article, various methods of risk analysis are compared and the shortcomings of each are presented. Numerical risk modeling is a modern method of risk analysis that provides easily measurable and comparable data, since each risk is transformed into a function of the probability distribution of the potential results. The result of analysis is a graph that presents exact project risk information. The most sensitive part of the model is determining the probability distribution of input variables. In this article, this is performed with the use of extant (world and Croatian) experiences in wind energetics projects.

On the basis of the risk analysis conducted, it is possible to conclude the following:

- wind power plant projects in Croatia are cost effective but with moderate financial indices. This concerns a relatively safe investment that is returned after 12 to 15 years,
- the greatest risks are in connection with the measurement of wind potential, since the production and earnings of a wind power plant depend on it. Measurement of the wind potential is the basic index of the cost effectiveness of a project, and taken very seriously by financial institutions. Therefore, obtaining credit for the construction of a wind power plant depends upon the quality of the measurement,
- in Croatia, the situation is still uncertain from the aspect of administrative risks (permits, approvals), which can significantly increase the time necessary for the preliminary work (prior to beginning construction). This situation will improve in the future but, unfortunately, not soon enough for the projects that are currently in the measurement phase.

Although conditions in Croatia apply to the reference case in the wind power plant project model, the model can be adapted to any market whatsoever. The main differences between Croatia and the rizika mogu se lako unijeti u model, a moguće je dodati i nove varijable. U uvjetima uređenog tržišta rezultati analize rizika bili bi pouzdaniji (manje rasipanje), budući da bi npr. ulazna varijabla Priključna TS bila određena za pojedinu lokaciju, dok je trenutno u Hrvatskoj potrebno predviđati ishod pregovora s HEP-om.

Štoviše, model je moguće primijeniti i na projekte drugih obnovljivih izvora energije, kao što su male hidroelektrane ili solarne elektrane. Budući da se model temelji na numeričkoj analizi rizika, može se, uz proširenja, primijeniti na gotovo svaki investicijski projekt. Monte Carlo metoda ima najrazličitije primjene, od financijskog tržišta, do socioloških analiza.

countries of the European Union are evident in the risks connected with administrative procedures, the model of incentives for renewable energy sources and property-legal questions. Changes with regard to the function of the probability distribution of individual risks can easily be entered into the model. It is also possible to add new variables. Under the conditions of an orderly market, the results of risk analysis will be more reliable (less dispersed). For example, the input connection substation variable should be  determined for an individual location, while currently in Croatia it is necessary to anticipate the outcome of the negotiations with HEP.

Moreover, the model can also be applied for projects involving other renewable energy sources, such as small hydroelectric power plants or solar energy. Since the model is based upon numerical risk analysis, with expansion it can be applied to nearly every investment project. The Monte Carlo method has the most varied applications, from the financial market to social analyses.

## LITERATURA / REFERENCES


[1] Energetski Institut Hrvoje Požar, Strategija energetskog razvitka, u okviru projekta Strategija razvitka Republike Hrvatske – Hrvatska u 21 stoljeću, 2002.

[2] Department for Environment, Food and Rural Affairs (DEFRA), Risk Management Strategy, DEFRA, Great Britain, April, 2004

[3] COOPER, D. F., GREY, S., RAYMOND, G., WALKER, P., (Broadleaf Capital International), Project Risk Management Guidelines Managing Risk in Large Projects and Complex Procurements, John Wiley & Sons Ltd, May, 2005

[4] MARRISON, C., The Fundamentals of Risk Measurement, New York, McGraw Hill, 2002

[5] RETScreen International Clean Energy Decision Support Centre, Wind Energy Project Analysis, CANMET Energy Technology Centre in corporation with NASA, UNEP and GEF, 2003

[6] HOWATSON, A., CHURCHILL, J. L., International Experience With Implementing Wind Energy, The Conference Board of Canada, February, 2006

[7] Wind Turbines IEC 61400-1, IEC, Geneva, Switzerland, 2005

[8] Marsh-Mercer Human Resource Consulting – Mercer Delta Organisational Consulting, Scoping Study on Financial Risk Management Instruments for Renewable Energy Projects, United Nation Division of Technology, Industry and Economics, 2002

[9] ČUPIĆ, M. E., TUMMALA, V.M.R., Savremeno odlučivanje: metoda i primena, Naučna knjiga, Beograd, 1991.

[10] URAN, V., Isplativost ulaganja vlastitog kapitala u projekt za zajedničku proizvodnju toplinske i električne energije, Energija, god. 54(2005), br. 3, Zagreb

[11] ŽIKOVIĆ, S., Formiranje optimalnog portfelja hrvatskih dionica i mjerenje tržišnog rizika primjenom VaR metode, magistarski rad, Sveučilište u Ljubljani, Ekonomski fakultet, Ljubljana, 2005.

[12] http://office.microsoft.com

[13] http://www.simularsoft.com.ar

[14] BERNASCONI, J., (ABB Switzerland Ltd., Corporate Research), Risk Tutorial, ABB Review, April, 2004



Uredništvo primilo rukopis:
2007-07-09

Prihvaćeno:
2007-07-15

Manuscript received on:
2007-07-09

Accepted on:
2007-07-15