UPOREDNE ANALIZE NEKIH SISTEMA ZA UPRAVLJANJE MOSTOVIMA

COMPARATIVE ANALYSIS OF SOME BRIDGE MANAGEMENT SYSTEMS

Radomir FOLIĆ
Doncho PARTOV

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1 UVOD

Mostovi su najznačajnija komponenta saobraćajnica. Oni imaju suštinsku ulogu u transportnim sistemima i u ekonomskom proizvodnom procesu. Prema EN 1990: 2002, procenjeni vek trajanja mostova jeste 100 godina, pa je potrebno osigurati ekonomičan rad mostova adekvatnim projektovanjem i građenjem, ali i upravljanjem. U svetu i regionu, najzastupljeniji su betonski mostovi (BM) čija trajnost često nije zadovoljavajuća. Stoga, razmatranja u ovom radu usmerena su upravo na njih. Njihova nosivost i njihove eksploatacione karakteristike opadaju tokom vremena, pa je i njihov eksploatacioni (životni) vek često kraći od očekivanog. Na to utiču i porast funkcionalnih zahteva i izloženost mostova agresivnom dejstvu okoline (vlaga, temperatura i aerozagađenje), a zimi – i soli za odmrzavanje. Poslednjih godina povećavaju se i težine i broj vozila na saobraćajnicama. To uslovljava stalno praćenje stanja mostova, te izvođenje manjih ili većih radova, da bi se omogućio nesmetan saobraćaj. Cilj upravljanja građevinskim objektima (GO) jeste očuvanje određenog stepena pouzdanosti funkcionisanja u toku životnog veka, uz optimizaciju troškova održavanja.

Transportne agencije (institucije) trebalo bi da održavaju mostove u prihvatljivim uslovima kako bi obezbedile poželjan nivo usluge korisnicima u okolnostima ograničenih budžeta, a neki od mostova brzo stare [1]. U mnogim zemljama razvijeni su sveobuhvatni sistem upravljanja mostovima i praksa inspekcije mostova. Ciljevi menadžera mostova jesu da osiguraju to da mostovi postignu svoj životni vek, da ostanu otvoreni za

Radomir Folić, dr, profesor emeritus, Univerzitet u Novom Sadu, Fakultet tehničkih nauka, Odeljenje građevinarstva i geodezije, 21000 Novi Sad, Trg D. Obradovića, N. Sad, Srbija; imejl: folic@uns.ac.rs
Doncho Partov, profesor, dr, Univerzitet za arhitekturu i konstrukcije – VSU, „Ljuben Karavelov", Sofija, Bugarska; imejl: partov@vsu.bg

1 INTRODUCTION

Bridges are the most important component of transportation systems and they play an essential role in the economy. According to EN 1990:2002 the desired service life of bridges is 100 years so it is necessary to secure the cost-effective service of bridges through an adequate design and construction, as well as management. Globally and in the region, concrete bridges (CB) are most common, but their durability is often unsatisfactory. Therefore, the considerations in this paper are focused on them. Their load-bearing capacity and service characteristics degrade over time, so their service life is shorter than expected. They are also influenced by increasing functional requirements and the exposure to the aggressive action of the environment (humidity, temperature and air pollution), and in winter also to de-icing salts. In recent years, the weight and number of vehicles on the roads have been increasing. This necessitates constant monitoring of the condition of bridges, and performing light or intensive maintenance works, in order to enable unhindered traffic flow. The goal of structural management (SM) is to maintain a certain degree of reliability during service life, while optimizing maintenance costs.

Transportation agencies should maintain bridges, a number of which are aging rapidly [1] in acceptable conditions to provide a desirable level of service to the users/public within limited budgets. In many countries comprehensive bridge management systems (BMS) and bridge inspection practices have been developed. The objectives of a bridge manager are to ensure that bridges

Radomir Folic, PhD, Professor emeritus, University of Novi Sad, Faculty of Technical Sciences, Department of Civil Engineering and Geodesy, 21000 Novi Sad, Trg D. Obradovića, N. Sad, Serbia
Doncho Partov, Professor, Ph.D., VSU, University of architecture and structures "Ljuben Karavelov", Sofia, Bulgaria

saobraćaj i da rizik od većih oštećenja i/ili rušenja uvek bude vrlo nizak. Sve to treba postići na održiv način i uz minimalne troškove. Neki aspekti upravljanja mostovima uglavnom su u vezi s pojedinačnim mostovima (nivo projekta), dok se drugi aspekti odnose na upravljanje grupom mostova (BM na nivou mreže [2]).

Uloga BMS-a od posebnog je značaja u optimizaciji troškova održavanja, za šta je neophodno koristiti sistematski i planirani pristup, zasnovan na tehničkim, ekonomskim i sociološkim aspektima. Prvenstveno, imaju se u vidu prioriteti, vrste i obim intervencionih mera, kao i odgovarajući troškovi. Ovakvi problemi uspešno se rešavaju razvojem i primenom informacionih sistema za upravljanje objektima. Opisane su različite vrste inspekcija/pregleda zbog znakova deterioracije (slabljenja svojstava), zbog curenja, prslina, deformacija, itd. Inspekcija se može obaviti da bi se naznačio način održavanja mostova. Cilj inspekcijskog održavanja (IO) jeste otkriti bilo koji kvar koji može prouzrokovati neprihvatljiv rizik sigurnosti ili upotrebljivosti. Svrha inspekcije sigurnosti jeste da identifikuje očigledne nedostatke koji predstavljaju opštu opasnost ili koji mogu da dovedu do nje, te stoga zahtevaju posebnu pažnju i/ili hitnu intervenciju.

Poslednjih godina, u svetu se pojavljuje sve više radova [3], [4], [5–7] u kojima se uporedno analiziraju iskustva više zemalja, naročito kada je reč o načinu inspekcije, ali i o ostalim elementima BMS-a, s ciljem unapređivanja sopstvenih metodologija, na osnovu iskustva drugih. Među njima je i [8], u kojem se upoređuju inostrana iskustva sa onima iz SAD, iako su oni znatno napredovali – i u pojedinim državama i na nivou Federacije. To nas je motivisalo da napišemo ovaj rad da bi se i u Srbiji i Bugarskoj radilo na unapređivanju BMS-a – po ugledu na druge zemlje, a osnova za to jesu uporedne analize. Međunarodna udruženja IABSE, RILEM, *fib*-međunarodno udruženje za beton (ranije CEB i FIP), ACI (Američki institut za beton), AASHTO (Američka asocijacija za puteve), kao i drugi, bave se aktivno upravljanjem mostovima putem preporuka za projektovanje trajnih konstrukcija, praćenje i procene stanja, kao i za obim i vreme radova na održavanju. To rade i pojedine države putem ministarstava za saobraćaj i/ili putem saobraćajnih agencija [11], i drugi. Mnogi od njih rade na tome i propisuju mere za adekvatno održavanje mosta već u fazi projektovanja kako bi se obezbedili pouzdanost i upotrebljivost mosta uz što manja ulaganja. Važni elementi, pored trajnosti mosta, takođe su pristupačnost inspekciji i pogodnost za održavanje konstrukcije mosta i okruženja.

U ovom radu prikazane su neke smernice za pregled mostova, utvrđivanje i vrednovanje stanja, što je osnova redosleda prioriteta aktivnosti (rejtinga) na održavanju ili rehabilitaciji. Komentarisan je razvoj BMS-a u Srbiji, kao i sistemi koji se primenjuju u nekim drugim državama, uz uporednu analizu. U radu su prezentovane neke analize dokumenata koji se odnose na BMS u Srbiji, Južnoj Africi, Kini, J. Koreji, Japanu, SAD, te u nekim zemljama Zapadne Evrope (npr. Engleska, Danska, Švedska, Nemačka).

achieve their design life, remain open to traffic continuously and keep the risk of failure always very low, achieving this sustainably at a minimum lifecycle cost (BM). Some aspects of bridge management are concerned primarily with the individual bridges (project – level B-M) whereas other aspects are concerned with the management of a stock of Bridges (network-level BM) [2].

The role of BMS is of a particular importance in the maintenance cost optimization, for which it is necessary to use a systematic and planned approach based on technical, economic and sociological aspects. They primarily concern the priority, type and scope of intervention measures, as well as the associated costs. Such problems are successfully resolved by the development and application of information systems for managing the structures. Inspections describe different signs of distress in CB, such as leakage, deflection, etc. An inspection can be carried out to indicate the way to maintain a bridge. The objective of maintenance inspection (MI) is to detect any defect which may cause an unacceptable safety or serviceability risk. The purpose of a safety inspection is to identify obvious deficiencies which represent, or might lead to, a danger to the public and therefore require special attention and/or immediate or urgent measure.

In recent years, an increasing number of papers have appeared in the world [3], [4], [5-7] in which the experiences of multiple countries are analyzed, especially regarding the method of inspection, and other elements of BMS with the aim of improving their own methodologies based on the experience of others. Among them is [8] which compares foreign experiences with those from the United States, at the state and at the Federal level. This motivated us to write this paper in order to encourage the work on the improvement of BMS in Serbia and Bulgaria, following the example of other countries, and the basis for that are comparative analyses. International associations IABSE, RILEM, *fib*-international concrete association (formerly CEB and FIP), ACI (American concrete institute), AASHTO (American Roads Association) [11], and others are actively involved in bridge management through recommendations for the design of durable structures, monitoring and condition assessments, scope and timing of maintenance work. This is also provided by the individual States through the Ministry of Transport and/or Transportation agencies. Many of them also develop and prescribe measures for adequate maintenance for bridges in the stage of design to secure their reliability and usability with minimum investment. Important elements also include requirements for durability, accessibility for inspection and suitability for maintenance.

This paper presents some guidelines for inspecting bridges, determining and evaluating their condition, enabling the prioritization and rating of maintenance or rehabilitation activities. The development of BMS in Serbia and Bulgaria and the systems applied in some other countries are commented on with a comparative analysis. This paper presents some analyses of the documents related to BMS in Serbia, Bulgaria; South Africa, China, S. Korea, Japan USA, and some Western Countries (UK, Denmark, Sweden, Germany, et al.).

2 ISTORIJSKI RAZVOJ BMS

U radu [9] navodi se da je u SAD 2009. godine postojalo više od 603.000 evidentiranih mostova. Razvoj BMS-a povezuje se sa izveštajima o katastrofalnim rušenjima (na primer, čuveni Silver most, 19. decembra 1967. godine, gde je poginulo 46 osoba). To je izazvalo Federalnu agenciju FHWA da ustanovi Nacionalni program pregleda mostova 1970. godine. Program je propisao da se mostovi pregledaju najmanje jednom u dve godine i da se formira inventarska baza mostova. Devedesetih godina XX veka, razvijeni su poznati softverski paketi PONTIS i BRIDGIT u SAD i DANBRO u Danskoj.

Najduže iskustvo sa upravljanjem ima Švedska (od 1940. godine), što je doprinelo kasnijem smanjenu procenta izdvajanja za održavanje, u odnosu na vrednost građenja. U Srbiji je Javno preduzeće za puteve 2009. godine publikovalo prevod njihovog priručnika za pregled mostova, ali on još uvek nije uklopljen u ukupni BMS.

Određivanje nosivosti mostova važno je i za formiranje prioriteta (ranga), a još uvek preovlađuje i može se preporučiti korišćenje determinističkog pristupa po ugledu na onaj koji se koristi u SAD (prikazano u radu [4]). Uporedni pregled BMS-a nekoliko država Evrope, među kojima su Srbija i Bugarska, prikazan je u Tabli 1, prema [10]

U tabeli su upisani podaci početka uvođenja BMS-a i vidi se da je to u Srbiji bilo 1985. godine, a u Bugarskoj – 2004/2005. U Srbiji je uveden sistem prioriteta (rejting), dok u Bugarskoj nije do 2009. godine. Broj mostova, obuhvaćenih BMS-om, u Srbiji jeste 3.500, a u Bugarskoj

2 HISTORY OF BMS

In [9] it is stated that in the USA in 2009, there were more than 603,000 bridges recorded. The development of BMS is related to reports of catastrophic collapses such as the famous Silver Bridge on December 15th, 1967 with 46 fatalities. This prompted the Federal Agency FHWA to establish the National Bridge Inspection Program in 1970. The program mandated that bridges be inspected at least once every two years and that an Inventory of Bridges be formed. In the 1990s, the well-known software packages PONTIS and BRIDGIT in the USA and DANBRO in Denmark were developed.

Sweden has the longest experience with management (since 1940), contributing to reduced allocations for maintenance, as a fraction of the value of construction. In Serbia, the Public Road Company published a translation of their Sweden Bridge Inspection Manual in 2009, but it was not incorporated into the overall BMS.

Determining the load - bearing capacity of bridges is also important for forming priorities (range). A deterministic approach, modelled on the one used in the United States [4] is recommended. A comparative overview of the BMS of several European countries, including Serbia and Bulgaria, is presented in Table 1 according to [10]. The table contains data on the beginning of the introduction of BMS. This occurred in Serbia in 1985 and in Bulgaria in 2004/2005. A system of prioritization was introduced in Serbia, while in Bulgaria it was not, until 2009. The number of bridges included in BMS in Serbia is 3.500, and in Bulgaria it is 1312. Scan point-Freissinet

Tabela 1. BMS u zemljama Evrope, prema [10]
Table 1. BMS in European country, after [10]

Država *Country*	God. uvođenja BMS *Year of BMS starting*	Prioretizacija BMS *Prioritization in BMS*	Broj mostova u sistemu *Numb. of bridge managed in BMS*	Korišćeni sistem/softver *Used system/software*
Bugarska *Bulgaria*	od 2004/05 *From 2004/05.*	Ne *No;*	1.312	*Scan print-Freissinet*
Hrvatska *Croatia*	u razvoju *Developed now*	Da *Yes;*	800 na auto-putevima *800 on motorways*	*Oracie 10.G*
R. Češka *Czech Republic*	*2002.*	Da *Yes;*	18.740	*IIS database+MS SQL Server*
Engleska *England*	*2001.*	Da *Yes;*	8.600	*Oracle*
Estonija *Estonia*	*2001.*	Da *Yes;*	922	*Pontis*
Francuska *France*	*1999.*	Ne *Not yet;*	9.000	*Own system*
Nemačka *Germany*	*2000/2001.*	Da *Yes;*	38.000	*SIB-Bauwerke; BMS-Optimisation-tools*
Mađarska *Hungary*	*1996.*	Da *Yes;*	6.000	Sopstveni sistem *Own system*
Italija *Italy*	*1986.*	Da *Yes;*	3.626	*Oracle, SQL server*
Litvanija *Latvia*	*2002.*	Da *Yes;*	1.775	*LatBruts*
Srbija *Serbia*	*1985.*	Da *Yes;*	3.500	*BPM*

– 1.312. *Softver Scan point-Fressinet* koristi se u Bugarskoj, a BPM – u Srbiji. Iako je u Srbiji otpočela primena BMS-a relativno rano, još uvek nije konstituisan jedinstven sistem. Priručnik za pregled mostova, koji se koristi u Švedskoj, 2009. godine je preveden na naš jezik, ali nije zvanično usvojen za primenu. Pregovarano je i s Francuskom, ali bez rezultata. Bugarska koristi francuski softver. I ostale evropske zemlje su na putu razvoja sistema i zaostaju u poređenju sa SAD.

Jedno poglavlje u [12] posvećeno je BMS-u i vrednovanju mostova u Srbiji. Propisi (1992) pokrivaju tehničke standarde za korišćenje i redovno održavanje mostova. Oni uključuju sledeće: sadržaj podataka koji se registruju (banka podataka); vrste inspekcija, kao i njihov sadržaj u vezi sa elementima mostova i specifikacije radova na redovnom održavanju. Održavanje razmatra inspekciju, uočavanje i registrovanje promena njihovog stanja, aktivnosti održavanja i mere za otklanjanje svih defekata i oštećenja. Sledeće vrste inspekcija obavljaju se u skladu s Jugoslovenskom pravilnikom (1992), citiranim u [12]: kontrolne inspekcije; redovne inspekcije; detaljne inspekcije; posebne inspekcije i vanredne inspekcije.

U Srbiji se aktivno radilo na uvođenju BMS-a, uz informatički (IT) aspekt baze podataka od 2001. godine, ali još uvek nije konstituisan jedinstveni BMS u Srbiji. Informacioni sistem o putevima (ISP) sadržao je bazu podataka (BP) o mostovima i BP o saobraćaju. U GIS-u, s podacima o prostoru, skladište se, edituju i svrsishodno koriste podaci o lokaciji objekata sa okolinom. U okviru Integrisanog sistema za puteve, struktura je bila: inventarski podaci o mostu; podaci o pregledima mostova (stanje mosta, rejting mosta, kategorija stanja elemenata, podaci o nosivosti); podaci o vanrednim prevozima; kao i planirani i izvedeni radovi. Autor BMS-a, rađenog na Institutu za puteve, po ugledu na sistema upravljanja mostovima u SAD i Organizaciju za ekonomsku saradnju i razvoj (OECD), bio je pok. D. Bebić. Počelo se s bazom podataka o mostovima, da bi postupno napredovao do procene nosivosti mostova [4]. Naglašen je multidisciplinarni karakter.

Opisani BMS zahteva dalju razradu uvođenjem finansijskih pokazatelja, koji bi vlasniku omogućili planiranje sredstava za održavanje, sistem procene stanja mostova u vezi sa sanacionim radovima, kriterijume za procenu, koji se koriste za utvrđivanje konstruktivne i funkcionalne adekvatnosti mosta. Tehnički propisi za održavanje konstrukcije mosta postojali su od 1992. godine. U slučaju kada je potrebno sprovesti mere revitalizacije mostova, optimalno rešenje se iznalazilo na osnovu istraživačkih radova, u skladu s posebnom procedurom.

Novija uporedna analiza prakse inspekcije mostova Kine, SAD, Japana i J. Koreje prikazana je u [1]. Standardi, priručnici i smernice, koji se koriste u navedene četiri zemlje, predstavljeni su i upoređeni. Predstavljeni su tipovi inspekcija i njihovi intervali, sistem izveštavanja o inspekciji, ocene stanja mosta, uz uporednu analizu. Na osnovu te analize, autori su zaključili da ove četiri zemlje pokazuju sličnosti u ukupnom procesu prakse inspekcije mosta i u programima upravljanja mostovima, poput upotrebe BMS-a u programu kontrole kvaliteta.

Međutim, razlike su iskazane iz aspekata detalja. Model narušavanja i funkcija ažuriranja, zasnovan na

software is used in Bulgaria, and BPM in Serbia. Although the implementation of BMS started relatively early in Serbia, a unified system has not yet been constituted. The Bridge Inspection Manual used in Sweden was translated in 2009 but has not been officially adopted for implementation. There were also negotiations with France but without results. Bulgaria uses French software. Other European countries are also developing the system and lag behind the United States.

One chapter in [12] is dedicated to BMS and bridge evaluation in Serbia. Regulations (1992) cover technical standards for utilization and regular maintenance of bridges. They include the following: contents of the data to be registered (data bank); kinds of inspections (control, regular, main and extraordinary), as well as their content regarding the elements of bridges; specification of works on regular maintenance. Maintenance considers inspection, observation and recording of changes and their condition, maintenance activities and measures for eliminating all defects and damage. The following types of inspections are performed according to the Yugoslav Regulation 1992, cited in [12]: Control inspections; regular inspections; detailed inspections; special inspections, and extraordinary inspections.

In Serbia, there has been active work on the introduction of BMS, with IT aspects of the database since 2001, and a single BMS in Serbia has not yet been constituted. The Road Information System (ISP) contained a database (BP) on bridges and a BP on traffic. In GIS, along with data on space and location of structures with their environment are stored, edited and purposefully used. The Integrated Road System had the following structure: inventory data on the bridge; data on inspections of bridges (bridge condition, bridge rating, and element condition category, bearing capacity data); data on emergency transport; and planned and performed works. The BMS was created at the Roads Institute, after the model of the bridge management system in the USA and the Organization of Economics Cooperation and Development (OECD) by the late D. Bebić. A bridge database started to gradually progress towards assessing the load-bearing capacity of bridges [4]. Its multidisciplinary character was prominent.

The described BMS requires its further elaboration by introducing financial indices which would enable the owner to plan the funds for maintenance, a system of evaluating the condition of bridges in connection with rehabilitation works, evaluation criteria used for the determination of structural and functional bridge adequacy. Technical regulations for the bridge structure maintenance existed until 1992. In cases requiring revitalization measures of bridges, optimum solutions are obtained on the basis of research works, in line with a special procedure.

A recent comparative analysis of the practice of inspection of bridges in China, USA, Japan and S. Korea was presented in [1]. Standards, manuals and guides used in the four countries are presented and compared. Inspection types, intervals, reporting systems, bridge condition ratings are also presented and compared. Based on this analysis the authors conclude that the four countries show similarities in the overall process of bridge inspection practices and bridge management programs such as the use of a BMS in quality control.

However, differences are shown in terms of detailed skladištenju podataka, ali i BMS-i nekih zemalja još se nisu pripremili i nisu uveli sve funkcije. Koreja, kao i mnoge druge zemlje, ne uključuje informacije o sigurnosti mosta ili model optimizacije rizika za održavanje troškova [4]. Sistem se može koristiti za procenu upotrebljivosti postojećih mostova. U tom smislu, razmatra se model za predviđanje procesa deterioracije elemenata postojećih mostova i povezuje se s planom održavanja ili rehabilitacije.

3 ZAHTEVI BMS

U mnogim zemljama, a i našem regionu, postavljaju se sledeća pitanja:

- kakvo je stvarno stanje mostova i da li je BMS koji se koristi adekvatan ili ga treba unaprediti?
- koliko košta da postojeće stare mostove dovedemo u stanje prihvatljivih performansi?
- da li su obezbeđene odgovarajuće podloge za adekvatne i optimalne intervencije na mostovima?

Upravljanje i održavanje uslovljavaju sistematsko praćenje – sisteme za upravljanje mostovima, što treba da omogući organizovano prikupljanje podataka za analize i procene u svim fazama životnog ciklusa, zavisno od značaja saobraćajnice i kompleksnosti objekta. U ovoj oblasti prednjače SAD. BMS je usmeren na postojeće mostove, da bi obezbedio ostvarenje njihovog projektovanog eksploatacionog veka, tj. to da u kontinuitetu budu otvoreni za saobraćaj i da se minimizira rizik od „otkaza" [2]. Termin upravljanje mostovima obuhvata široki opseg aktivnosti, prvenstveno inspekcije – nadgledanje, procene budućeg stanja putem modela deterioracije tokom vremena za određivanje prioriteta za izvođenje radove na održavanju. Potrebno je određivanje nosivosti mosta, naročito kada je potrebno prevesti vangabaritne terete, kao i različita ispitivanja. Rezultat tih aktivnosti jeste racionalnije održavanje mosta i okoline.

U SAD na realizaciji BMS radi se u pojedinim državama, ali i na nivou Federacije [11]. Upravljanjem se najčešće obuhvata skup mostova na saobraćajnoj mreži, a ređe pojedinačnih mostova; jedan od primarnih zadataka jeste vrednovanje njihovog stanja i brzina propadanja (deterioracije). Značajno je obezbediti kvalitetne projekte i njihovu realizaciju, da bi se dostigao proračunski eksploatacioni vek, odnosno bitno je realno ga predviđati [4] i [9]. Zbog ograničenih sredstava, moraju se odrediti i uvažavati pomenuti prioriteti za realizaciju radova. Da bi se to ostvarilo, potrebno je odrediti stvarno stanje konstrukcije setom pregleda koji se redovno obavljaju, u pravilnim vremenskim razmacima. Uvek se u BMS-u postavlja uslov da postupci pregleda budu standardizovani, da bi bili ujednačeni i objektivni, jer ih obavljaju stručnjaci različitog nivoa znanja i različitih kriterijuma. Adekvatni upitnici – ni suviše opširni, niti nepotpuni – obezbeđuju brži, jeftiniji i realniji pregled. Sve više se uvodi planiranje životnog ciklusa mosta, kojim sa obuhvata koštanje – od projektovanja, građenja, upravljanja, do uklanjanja objekta. Upravljanje životnim ciklusom zasniva se na ekonomičnosti, uz istraživanje mogućnosti optimizacije faktora, kao što su troškovi, profit, rizik i kvalitet, trajnost, održivost, itd. [4]. Upravljanje kvalitetom (QM) jeste sveobuhvatan pristup za sve faze stvaranja do zamene objekta [9] i [15]. U radu [16], preporučuje se i u

aspects. Deterioration model, and updating function, based on data storage but the BMSs of some countries have not yet prepared for all features. Korea does, as well as many other countries, not include information on bridge safety or a risk optimisation model for cost maintenance. In addition, many papers also compare some components of BMS of individual States and recommendations of the associations, and this can be commented upon in the further presentation with tabular reviews. Development of BMS in Japan, for individual bridges, which is integrated into the Miyamoto concrete bridge expert rating system, is cited in [4]. The system can be used to assess the serviceability of existing bridges. In that sense, a model for predicting the process of deterioration model of the elements of existing bridges is considered and linked with the plan of maintenance or rehabilitation.

3 REQUIREMENTS FOR BMS'S

In many countries, as well as in our region, questions are being asked:

- What is the real condition of bridges and is the BMS being used adequate or should it be improved?
- How much does it cost to bring the existing old bridges to the state of acceptable performance?
- Are adequate datasets provided for adequate and optimal interventions on the bridges?

Management and maintenance require systematic monitoring – the monitoring of Bridge Management System (BMS) should enable organized data collection for analysis and assessment at all stages of the life cycle depending on the importance of the road and the complexity of the structure. The United States are the leaders in this area. BMS should be focused on the existing bridges with a goal to ensure the realization of their designed service life, i.e. to keep them continuously open for traffic, and minimize the risk of "failure" [2]. The term bridge management comprises a wide range of activities, primarily monitoring-inspections, assessments of future condition through models of deterioration over time to determine priorities for performing maintenance work. The load-bearing capacity of the bridge, especially under oversized loads should be determined, and various tests should be performed. These activities should result in a more cost-effective maintenance of the bridges and the environment.

In the USA, the realization of BMS is being worked on both in individual states and at the Federal level [11]. Management usually includes a set of bridges in the traffic network, and less often individual bridges, and one of the primary tasks is to evaluate their condition and rate of deterioration. It is important to provide quality designs and their realization of service life and provide its realistic prediction [4] and [9]. Due to limited funds, the mentioned priorities for the realization of works should be determined and observed. In order to achieve that, it is necessary to determine the actual condition of the construction by a set of inspections that are regularly performed at regular intervals. BMSs always set the condition that the review procedures be standardized, in order to be uniform and objective, because they are performed by experts with different levels of knowledge and criteria. Adequate questionnaires, neither too extensive nor incomplete, provide a faster, cheaper and more realistic overview.

BMS-u primena savremene informacione BIM tehnologije (tehnologija za modeliranje građevinskih informacija).

Razmatranje BMS-a nerazdvojivo je od trajnosti konstrukcije mostova čija je izloženost nepovoljnim dejstvima okoline izražena [11]. Održavanje mostova predstavlja skup svih mera i postupaka, koji se preduzimaju tokom eksploatacionog veka da bi se postigla potrebna trajnost, uz ostvareni nivo sigurnosti i upotrebljivosti [4]. Pri tome se koriste priručnici/smernice za pregled mostova, često zvanični dokumenti pojedinih država. U njima se pored tekstualnog dela grafički prilozi prikazuju karakteristične delove konstrukcije mosta, opreme i neposrednog okruženja mosta [17]. U nekim radovima se upoređuje deterministički i probabilistički pristup upravljanju [18]. Od značaja je i predviđanje budućeg stanja mosta, modelom deterioracije, radi optimizacije troškova. Većina naših stručnjaka oslanja se samo na Evrokodove (EN), iako su dokumenti [15] savremeniji.

Procene koje se obavljaju primenom metodologije koju je razvila Evropska komisija istraživanja transporta (EKIT) i Sistem za monitoring i informacije (EKIT) i informacije monitoringa i informacionih sistema (TRIMIS) [6]. Izveštaj je kritička analiza s preporukama i istovremeno osvetljava nove tehnološke razvoje i buduće orijentisane pristupe. Te metodologije su primenjene u Italiji, Švajcarskoj, Austriji, Nemačkoj, Francuskoj, Portugaliji i Grčkoj [5]. O strategiji upravljanja pouzdanošću mostova, zasnovanoj na pouzdanom semi-markovljevom i determinističkom modelu, dato je [17]; u Sabahu [3]; u Iranu [5]; i u Italiji [19]. Evropska iskustva i BRIME prikazani su u [20]. Za države u SAD, Federalna agencija za autoputeve (FHA) prikazala je komparativnu analizu u [11]. Pregled probabilističkog projektovanja eksploatacionog veka i održavanja šire je razmatran u [18]. Polazi se od toga da je eksploatacioni vek konstrukcije određen projektovanjem i građenjem, ali i njenim upravljanjem. Matematički model performansi uključuje proces starenja, slično modeliranju pri projektovanju konstrukcije.

4 INSPEKCIJA U REGULATIVI I PRAKSI

Zbog značaja pregleda (inspekcija) objekata i njihovog okruženja, sve države publikovale su smernice s mnoštvom ilustracija. Neke smernice su veoma obimne (npr. Ontario [4]), a neke su manje. Potrebno je sažeto objašnjenje pojmova i delova mostova, sa smernicama za aktivnosti [4] i [2], kao i federalni priručnik [11]. U [11], uvršteno je nekoliko dokumenata, mađu njima smernice za ocenu stanja u eksploataciji i o rutinskom održavanju mostova. Osnovni cilj pregleda mosta i njegovih komponenata jeste registrovanje defekata i oštećenja, koji utiču na sigurnost i upotrebljivost, i/ili povećanje stepena propadanja koje redukuje njihov životni vek. U Velikoj Britaniji postoje opšti, glavni i specijalni pregledi. Opšti pregledi se obavljaju svake druge godine i zasnivaju se na vizuelnom pregledu iz pristupačnih pozicija, pomoću durbina i veštačkog osvetljenja [17].

Increasingly, bridge life cycle planning is being introduced, which includes costs from design, construction, and management to demolition of the structure. Life cycle management is based on cost-effectiveness while exploring the possibilities of optimizing factors such as cost, profit, risk and quality, durability, sustainability, etc. [4]. Quality management (QM) is a comprehensive approach to all phases since the creation of a structure to its replacement [9] and [15]. In the paper [16], the application of modern information BIM technology in BMS (Building Information Modeling Technology) is also recommended.

The consideration of BMS is inseparable from the durability of bridge structures whose exposure to adverse environmental impacts is pronounced [11]. Bridge maintenance is a set of all measures and procedures that are taken during the service life in order to achieve the required durability with the achieved level of safety and serviceability [4]. In doing so, bridge inspection manuals/guidelines are used to inspect bridges, often official documents of individual countries. In addition to the textual part, the graphic illustrations show the characteristic parts of the bridge structure, equipment and the immediate surroundings of the bridge [17]. Some papers compare the deterministic and probabilistic approach to management [18]. It is also important to predict the future condition of the bridge, using a deterioration model, in order to optimize costs. Most of our professionals rely only on Eurocodes (EN), although the documents [15] are more up-to-date.

Assessments are performed using the methodology developed by the European Commission for Transport Research and Information Monitoring and Information Systems (TRIMIS) [6]. The report performs a critical analysis with recommendations and techniques while highlighting new technological developments and future-oriented approaches. They have been used in Italy, Switzerland, Austria, Germany, France, Portugal and Greece [5]. On the reliability management strategy of bridges based on reliability Semi-Markov deterministic model [17]; in Sabah [3]; in Iran [5]; in Italy [19]. European experiences and BRIME are presented in [20]. For the states in the United States, the Federal Highway Agency (FHA) presented a comparative analysis in [11]. An overview of probabilistic design of service life and maintenance is discussed in more detail in [18]. It is assumed that the service life of the structure is determined by design and construction, but also by its management. The mathematical performance model involves an aging process similar to modelling in structural design.

4 INSPECTIONS IN CODES AND PRACTICE

Due to the importance of inspecting structures and their surroundings, all the states have published guidelines with many illustrations. Some guidelines are very extensive, such as Ontario [4], and some smaller ones are concisely explained terms and parts of bridges with guidelines for activities [4] and [2] as a federal handbook [11]. In [11], several documents were included, including guidelines for assessing the condition in operation and routine maintenance of bridges. The main goal of the inspection of the bridge and its components is to register defects and damages that affect safety and usability and/or reduce their service life by increasing the

Opšti pregledi (inspekcija) mora pružiti informacije o fizičkom stanju svih vidljivih elemenata i mora sadržati vizuelni pregled svih delova bez posebne opreme za pristup ili posebno upravljanje saobraćajem. Glavni pregledi moraju pružiti sveobuhvatne i detaljne informacije o fizičkom stanju svih pregledanih delova konstrukcije objektu na putu. Tehnike inspekcije uključuju kucanje čekićem radi otkrivanja i uklanjanja betonskog zaštitnog sloja betona; obavljaju se najmanje jednom u šest godina. Posebni/specijalni pregledi konstrukcija sa ograničenjima težine, pre i posle prevođenja nenormalnih/teških tereta preko mosta, ukoliko je sleganje veće od dozvoljenog ili građevina izloženih incidentnim oštećenjima (npr. rečni mostovi nakon poplave onda je nužan i podvodni pregled). Inspekcija za procenu uključuje parametre potrebne za utvrđivanje nosivosti elemenata, uključujući moguće nedostatke (npr. naprsline, korozija, sleganje, neadekvatan materijal, sistem za odvodnjavanje). Raspored pregleda/inspekcija, priprema za to, evidencija (lokacija, ozbiljnost, obim i vrsta defekata i oštećenja) potrebni su da bi se obavila procena konstrukcije. Pristup za pregled može biti merdevinama, skelama, pokretnim podiznim radnim platformama, vozilima sa hidrauličnim platformom. Znakovi preopterećenja/slabljenja svojstava u armiranobetonskim (AB) konstrukcijama (defekti i oštećenja), AB greda i ploča (naprsline i pukotine) moraju se registrovati. Profil kolovozne ploče mosta treba proveriti zbog prekomernih ugiba ili nagiba [2].

U Srbiji je propisano nadgledanje betonskih mostova 1992. godine, a zatim i u Zakonu o putevima (1993). U njima su propisane aktivnosti bitne za BMS. Cilj redovnih pregleda jeste direktno kontrolisanje stanja građevine i održavanje bezbednosti u saobraćaju na zadovoljavajućem nivou. Kontrolne preglede obavlja inspektor puta, najmanje jednom mesečno. Zbog toga, pored praćenja nedostataka u dogledno vreme, potrebno je proučiti svu dostupnu dokumentaciju kako bi se utvrdili, pre svega, uzroci nastanka oštećenja. Započinje inicijalnim vizuelnim pregledom, s ciljem da se dobiju potrebni podaci o obimu i načinu detaljne inspekcije. Pre svega, potrebno je obezbediti siguran pristup oštećenoj konstrukciji. Na osnovu vizuelnog pregleda, utvrđuje se obim detaljnih metoda ispitivanja i ispitivanja [12].

Cilj detaljnog pregleda jeste dobijanje informacija o optimalnom obimu kako bi se procenilo stanje konstrukcije, kao i mogućnost dalje upotrebe, uz neophodne intervencije. Detaljni pregledi mostova trebalo bi da se rade najmanje jednom u dve godine. Tokom pregleda, uključuju se svi elementi mosta. Tokom specijalnih/posebnih pregleda, koriste se posebna oprema i posebni merni instrumenti, radi provere stvarnog stepena oštećenja utvrđenih redovnim ili povremenim pregledom, naročito na građevinama za koje je ustanovljeno da su sklone padu ili intenzivnoj deterioraciji, što iziskuje hitne popravke. Specijalni pregledi obavljaju se prema ranije planiranom programu. Vanredni pregledi obavljaju se prema pravilima redovnog pregleda, nakon neočekivanog događaja, kao i pre i posle prevoza vanrednih tereta koji mogu ugroziti kapacitet nosivosti ili funkciju konstrukcije. U slučaju oštećenja, oprema za inspekciju je ista kao i tokom specijalnog pregleda [12].

degree of deterioration. There are general, main and special examinations in the UK. General ones are performed every other year, and are based on visual inspection from accessible positions using binoculars and artificial lighting [17].

General inspection must provide information on the physical condition of all visible elements and comprise a visual inspection of all parts without special access equipment or traffic management arrangements. Principal inspection must provide comprehensive and detailed information on the physical condition of all inspectable parts of a highway structure. Inspection techniques include hammer tapping to detect elimination of concrete cover (six-year intervals). Special inspections for structures with weight restrictions, before and after having to carry abnormal heavy load, if settlement is greater than allowed for or structures subjected to accidental damage, river bridge after flooding (underwater inspection). Inspection for assessment includes parameters needed to determine the strength of members including possible deficiencies (cracks, corrosion, settlement, defective material, drainage system, etc.). Scheduling of inspection, preparation for it, records (location, severity, extent and type of defects and damage) needed to carry out a structural assessment. Access for inspection may be by ladder, scaffolds, mobile elevating work platform, vehicles with a hydraulic operated walkway. Signs of distress in RC S (defects and damage) of RC beams and slabs, cracks) must be registered. Profile of bridge deck may need to be checked for sagging or unusual deflection [2].

In Serbia monitoring of concrete bridges was prescribed in 1992, and afterwards the Regulation on the roads of 1993. The activities important for BMS are prescribed in them. The aim of regular inspections is to control the state of a structure directly and keep the traffic safety on a satisfactory level. Control inspections are done by a road inspector, at least once a month. Due to that, in addition to monitoring of deficiencies in due time, it is necessary to study all available documentation in order to define, in the first place, the causes of occurrence of the damage. It begins with an initial visual inspection which is meant to obtain data concerning scope and way of detailed inspection. Primarily, it is necessary to provide a safe access to the damaged structure. On the basis of the visual inspection the scope of detailed inspection and testing methods are determined [12].

A detailed inspection is aimed to obtain information on an optimal scope in order to assess the condition of structure and possibility of further use with necessary interventions. Detailed inspections of bridges should be done at last once in two years. During the inspection all elements of the bridge are included. During special inspections, special equipment and measuring instruments are used in order to check the actual degree of damage, especially at structures for which it has been established, by the regular or occasional inspection, to be in at risk of falling down or ruining, which requires urgent repairs. A special inspection is conducted according to a previously planned program. Extraordinary inspections are conducted according to the regular inspection rules after an unexpected event, as well as before and after the transportation of an extraordinary load which might endanger the capacity or function of the structure. In the case of damage, equipment for the inspection is the same as during the special inspection [12].

5 UPOREĐIVANJE NEKIH ELEMENATA BMS-A

Najčešće se mostovi i nadvožnjaci klasifikuju prema njihovim rasponima i statičkom sistemu. Međutim, već na rasponu od 2,0 m uvodi se obaveza pregleda, jer se to tretira kao most. Britanci uvode najmanju vrednost raspona od 1,80 m, a Južna Afrika – 6,0 m. Sistem ocenjivanja mosta u Velikoj Britaniji prikazan je u tabeli 2, sa određenim normama i opisima, prema [8]. Takođe, prikazno je nekoliko detaljnih opisa oštećenja, s njihovim uticajem na funkciju mosta, kao i definicije komponenti mosta.

5 COMPARISON OF SOME ELEMENT OF BMS

Most frequently bridges and overpasses are classified according to their span and statical system. At a span of 2.0 m the inspection mandate applies, as this is treated as a bridge. The British introduce the least value of the span of 1.80 m and the South Africa of 6.0 m. The bridge status assessment system in Great Britain is presented in table 2, with certain norms and descriptions, after [8]. Several detailed descriptions of defects with their impact on the bridge function, and definition of bridge components are presented, also.

Tabela 2. Vrste inspekcije mosta – Ujedinjeno Kraljevstvo [17]
Table 2. Types of bridge inspection – United Kingdom [17]

Vrsta inspekcije *Inspection Type*	Interval *Interval*	Realizuje *Performed by*	Opis *Description*
Prihvatanje *Acceptance*	Nije primenljivo *Not applicable (N/A)*		Kada se promeni vlasnik ili po završetku sklopi ugovor o održavanju objekta *When responsibility for the structure changes hands; i.e., on completion of construction of construction, when contracts for maintenance change*
Površno *Superficial*	Zahteva *Requent*	Izvođač *Contractor*	Osoblje izvođača radova treba da prati i u svakom trenutku prijavi sve što zahteva hitnu pažnju, kao što su oštećenja na gornjoj konstrukciji, nosačima mosta, oštećenja od poplave, dilatacione sprave, itd. *The contractor staff is encouraged to be vigilant at all times and report anything needing urgent attention, such as impact damage to superstructure, bridge supports, flood damage, expansion joints, etc.*
Opšti *General*	Na 2 godine *2 years*	Izvođač *Contractor*	Vizuelni pregled svih delova konstrukcije, koji ne zahtevaju posebnu opremu. *A visual inspection of all parts of the structure that can be inspected without special access equipment*
Glavni *Principal*	na 6 godina *6 years*	Izvođač *Contractor*	Vizuelni pregled na dodir pomoću posebne opreme za pristup *Touching-distance visual inspection using any necessary access equipment.*
Specijalni *Special*	Po potrebi *As necessary*	Izvođač *Contractor*	Istražiti neke utvrđene nedostatke. *To investigate some identified defect*

Tabela 3. Inspekcije i nadzor na programu pregleda, prema [8]
Table 3. Inspections and supervision by inspection program, after [8]

Program pregleda *Inspect. Program*	SAD *USA*	Danska *Denmark*	Finska *Finland*	Francuska *France*	Nemačka *Germany*	Norveška *Norway*	Južna Afrika *South Africa*	Švedska *Sweden*	Velika Britanija *United Kingdom*
Površno *Superficial* Opšte *General* Glavno *Principal* Posebni *Special*	Rutinski *Routine* Rutinski 48 meseci *Routine 48-manth* Dugotrajno 120 meseci *In depth 120 manth*	Dnevno *Daily* Rutinski *Routine* Glavno *Principal* Ekonomski *Economic* Posebni *Special*	Godišnje *Annual* Opšte na 5 godina *General 5 years* Opšte na 8 godina *General 8 years* Posebni *Special*	Rutinski *Routine* Godišnje *Annual* Predstava kvaliteta umetničkog dela *IQOA**	Površno *Superficial* Manji *Minor* Ozbiljni *Major*	Opšti *General* Ozbiljni *Major* Posebni *Special*	Praćenje *Monitoring* Glavni *Principal* Na nivou projekta *Project-Level*	Površni *Superficial* Opšte *General* Ozbiljni *Major* Posebni *Special*	Površno *Superficial* Opšte *General* Glavni *Principal* Posebni *Special*

*IQOA = Image de la Qualite des Ouvrajes d'Art

Uporedni podaci pregleda/inspekcija i nadzora po inspekcijskom programu u SAD, J. Africi, Velikoj Britaniji i šest evropskih zemalja sažeti su u tabeli 3. Za iste zemlje, u tabeli 4 sumirani su podaci pregleda i preporuka za održavanje i popravku.

Pored Velike Britanije i pomenutog priručnika [17], inspekcija mostova je najčešće propisana na nivou država, uključujući i SAD. Kao primer, pominje se priručnik Departmana za transport (DOT) Masačusetsa [21], gde je – pored uputstava za pregled na terenu i beleženja podataka – navedeno uputstvo za pisanje izveštaja. Slične priručnike koriste i Njujork, Džordžija, Florida i druge države, a federalna agencija je to sintetizovala i publikovala priručnik [8]. Inspekcija za održavanje i ocenjivanje/rejting analizirani su u priručniku [22], a pored inspekcije, jedno poglavlje posvećeno je jednom od novijih metoda praćenja stanja/„zdravlja" mostova (BHM) [23].

Najšire su problemi u vezi s BMS-om razmatrani u Priručniku [2], i u poglavljima posvećenim deterioraciji, istraživanjima, nadgledanju i proceni. Od značaja je predviđanje stanja postojećih mostova, kao i formiranje modela deterioracije mosta, što je predmet radova [10], [24] i [25]; razvoj BMS-a, zasnovanog na modeliranju informacija o građevini, analiziran je u [26].

Pored programskih paketa sistema/softvera koji su korišćeni u nekim državama Evrope i navedeni u tabeli 1, u tabeli 5 prikazan je 21 BM Sistem, koji se koriste širom sveta. Neke države koriste i više sistema (npr. Kanada i SAD).

Comparative data of inspections and supervision by inspection program in USA, S. Africa, U.K. and six European countries are summarized in table 3. For the same countries data of inspection and maintenance and repair recommendation are summarised in table 4.

In addition to the U.K. and the mentioned manual [17], bridge inspection is most often regulated at the state level, including the USA. An example is the Massachusetts Department of Transportation (DOT) manual [21], which provides instructions for writing reports in addition to field inspection and data recording instructions. Similar manuals are used in New York, Georgia, Florida, and other states, and the federal agency has synthesized and published the manual. Maintenance inspection and rating were analyzed in the BE Handbook [8]. Inspection for maintenance and rating system in BE Handbook [22] are analysed. Supplementing inspections, one chapter is dedicated to one of the newer methods of Bridge Health Monitoring (BHM) [23].

The problems related to BMS are most extensively considered in the Manual [2], with chapters devoted to deterioration, investigation, monitoring and assessment. In addition, the condition prediction of existing bridges is important, as well as forming the bridge deterioration model, which is the subject matter of 13], [24] and [25]. The development of BMS based on Building Information Modelling is analyzed in [26].

In addition to the systems / software used in some European countries and listed in Table 1, Table 5 shows the 21 BM Systems used worldwide. Some countries use more systems such as Canada and the United States.

Tabela 4. Preporuke za preglede, održavanje i sanacije, prema [8]
Table 4. Inspections and maintenance and repair recommendations, after [8]

Akcije *Actions*	SAD *USA*	Danska *Denmark*	Finska *Finland*	Francuska *France*	Nemačka *Germany*	Norveška *Norway*	Južna Afrika *South Africa*	Švedska *Sweden*	Velika Britanija *United Kingdom*
Čišćenje *Cleaning* Sve akcije *All Actions* Troškovi i količine *Costs nd Quantities*	Rutinski *Routin* Posebni *Special*	Rutinski *Routine* Glavni *Principal* Ekonomski *Economic* Posebni *Special*	Godišnji *Annual* Opšti na 5 godina *General 5 years* Opšti na 8 godina *General 8 years*	Godišnji *Annual* Predstava kvaliteta umetničkog dela *IQOA**	Manje *Minor* Ozbiljni *Major* Posebni *Special*	Opšti *General* Ozbiljni *Major* Posebni *Special*	Praćenje *Monitoring* Glavni *Principal* Na nivou projekta *Project-Level*	Površno *Superficial* Opšte *General* Ozbiljni *Major* Posebni *Special*	Površno *Superficial* Opšte *General* Glavno *Principal*

*IQOA = Image de la Qualite des Ouvrajes d'Art

Tabela 5. Dvadest jedan BMS korišćen u svetu, prema [26]
Table 5. Twenty one BMS used worldwide, after [26]

Br. *No.*	Država / *Country*	Ime sistema / *System name*	Skraćenica *Abbreviation*	Prva verzija *First version*
1	Kanada / *Canada*	*Ontario BMS*	OBMS	2002
2	Kanada / *Canada*	*Quebec BMS*	QBMS	2008
3	Kanada / *Canada*	*EBMS*	EBMS	2006
4	Kanada / *Canada*	*PEIBMS*	PEIBMS	2006
5	Danska / *Denmark*	*DANBRO BMS*	DANBRO	1975
6	Finska / *Finland*	*The Finish BMS*	FBMS	1990
7	Nemačka / *Germany*	*Bauwerk Management System*	GBMS	N/A
8	Island / *Ireland*	*Eirspan*	Eirspan	2001

9	Italija / *Italy*	Autonomna pokrajina Trento BMS *Autonomous Province of Trento BMS*	APTBMS	2004
10	Japan / *Japan*	Institut za regionalno planiranje Osake BMS *Regional Planning Institute of Osaka BMS*	RPIBMS	2006
11	Koreja / *Korea*	Korejski posl. sistem za održavanje puteva *Korea Road Maintenance Business System*	KRBMS	2003
12	Litvanija / *Latvia*	*Lat Brutus*	*Lat Brutus*	2002
13	Holandija / *Netherland*	*DISK*	DISK	1985
14	Poljska / *Poland*	*SMOK*	SMOK	1997
15	Poljska / *Poland*	*SZOK*	SZOK	2001
16	Španija / *Spain*	*SGP*	SGP	2005
17	Švedska / *Sweden*	Sistem upravljanja mostom i tunelima *Bridge and Tunnel Management System*	*BaTMan*	1987
18	Švajcarska / *Switzerland*	*KUBA*	*KUBA*	1991
19	SAD / *USA*	*Bridgit*	*Bridgit*	1993
20	SAD / *USA*	*Pontis*	*Pontis*	1992
21	Vijetnam / *Vietnam*	*Bridgemann*	*Bridgemann*	2001

Najznačajnija primena savremenih BMS-a može se uočiti u SAD. Glavni BMS koji se koristi u SAD jeste Pontis, razvijen početkom devedesetih za FHVA, a postao je AASHTO „proizvod" 1994. godine. On beleži, čuva i usmerava podatke o popisu i inspekcijama mosta, simulirajući stanje i predlažući akcije, razvijajući politiku zaštite/očuvanja i razvijajući ukupni program upravljanja mostom. Sistem omogućuje predstavljanje mosta kao skupa konstruktivnih elemenata, pri čemu se za svaki element izveštava na osnovu njegovog stanja. Sistem Bridget, razvijen 1985. godine Nacionalnim kooperativnim istraživačkim programom za auto-puteve (NCHRP), sličnih je katakteristika kao Points.

Nedavno evropsko iskustvo predstavljeno je u TISBO sistemu za održavanje infrastrukture, razvijenom u Holandiji. To je sistem koji integriše registraciju nakon inspekcije i upravljanje održavanjem. Evropska komisija uspostavila je brojne istraživačke projekte, a objavljene su i neke smernice koje se bave procenom postojećih mostova u Evropi, BRIME (2001), COST345 (2004), SAMARAS (2005) i održivim mostovima (2006). Sistem inspekcije, koji obuhvata vizuelni pregled, propisan je standardom BRIME i italijanskim normama/kodom. Ovu inspekciju može obaviti osoblje za održavanje puteva kako bi utvrdilo njihovo stanje, bez posebne opreme, samo vizuelnim pregledima [19].

Procena stanja na osnovu iskustva u Velikoj Britaniji uvela je vrednovanje stanja koja varira od 1 do 5 i odgovara preciznoj grupi oštećenja elementa koja je vezana za stanje (tabela 6). Konstrukcija mosta može se podeliti na njegove osnovne komponente (za konstrukcijski kapacitet i bezbednost od urušavanja) i nekonstrukcijske elemente (relevantno za funkcionalnost i dugotrajnost konstrukcije). Svakom elementu dodeljuje se različita težina W, koja varira od 10 (maksimalna važnost) do 5 (minimalna važnost). Lokacijski faktor (LF) odgovara svakoj težini, kao što je prikazano u tabeli 7.

Danska direkcija za puteve prikuplja ocene stanja za 13 komponenti mosta: celokupna konstrukcija; zidovi krila; kosine i kegle; oporci; međuoslonci; ležišta; nosiva gornja konstrukcija; hidroizolacija; krajnje grede; zaštitna barijera; površine; dilatacione spojnice, i druge komponente. Ukupna rejting skala je 0 do 5, a „0" znači nema oštećenja i „5" komponente više ne mogu da funkcionišu. Delovi mosta identifikovani su u

The most significant application of contemporary BMS's can be found in the USA. The principal BMS used in US is Pontis, developed in the early 1990s for the FHWA and it became an AASHTO product in 1994. It records, stores and directs data on the inventory and inspections of the bridge, simulating the situation and proposing actions, developing a preservation policy and developing an overall bridge management program. The system allows representation of bridge as a set of structural elements, where each element is reported based on its condition. The Bridget system, developed in 1985 by the National Cooperative Highway Research Program (NCHRP), has a capability similar to the Points.

A recent European experience is the TISBO Infrastructure Maintenance Management System, developed in Netherland. It is a system that integrates inspection registration and maintenance management. A number of research projects have been established by the European Commission and some published guidelines dealt with the assessment of existing bridges in Europe, BRIME (2001), COST345 (2004), SAMARAS (2005) and sustainable bridges (2006).

The inspection system, which includes a visual inspection, is prescribed by the BRIME standard and the Italian code. This inspection can be undertaken by the road maintenance staff to ascertain their condition, without special equipment, only by visual inspections [19]. The Evaluation of the condition based on the UK experience introduced a condition value which varies from 1 to 5, and corresponds to the condition of the related precise group of defect of the element (table 6). The bridge structure can be divided into its fundamental components (for the structural capacity and safety against collapse) and non-structural elements relevant for functionality and durability of the structure. A different weight W assigned to each elements varies from 10 (maximum importance) to 5 (minimum importance). A location factor (LF) corresponds to each weight, as shown in (table 7). The Road Directorate of Denmark collects condition ratings for 13 bridge components: entire structure; wing walls; slopes; abutments; intermediate supports; bearings; load-carrying superstructure; water-proofing; end beams; safety barrier; surfacing; expansion joints; and other components. The overall rating scale is 0 to 5, with "0" meaning no damage and "5" that the hijerarhijskom sistemu numerisanja, koji inspektorima omogućava da dodele/vrednuju stanje i zapišu zapažanja o delovima mostova (kolovozna ploča, gornja konstrukcija, donja konstrukcija). U Norveškoj praksi izveštava se o oceni stanja elementa mosta i identifikuju se određene vrste oštećenja koja su registrovana. Ocene stanja (CR) dodeljuju se na skali od 1 do 4, a 1 označava dobro stanje. Ocena stanja daje se za sve četiri posledice stanja elemenata: nosivost, bezbednost u saobraćaju, troškovi održavanja i estetika.

Francuska praksa u oceni stanja koristi skalu od 1 do 3. Područja 2 i 3 podeljena su prema hitnosti održavanja/intervencije. U Nemačkoj, ocena stanja CR-a kreće se od 0 (dobro) do 4 (veoma loše). Svakoj komponenti mosta dodeljene su tri ocene: jedna za oštećenja građevine, sigurnost u saobraćaju i trajnost mosta [8]. U mnogim dokumetima se ističe da trajnije konstrukcije imaju duži eksploatacioni vek i da se znatno lakše i jeftinije održavaju [13].

components can no longer function. Bridge components are identified in a hierarchical numbering system that allows inspectors to assign conditions and record observations about general regions of the bridges (deck, superstructure, and substructure). Norwegian practice reports condition ratings for bridge element and identifies specific types of damage that are observed. Condition ratings (CR) are reported on a 1 to 4 scale, with 1 indicating good condition. CR are provided for each four consequences of element condition: strength, traffic safety, maintenance cost and aesthetics. French practice reports CR on a 1 to 3 scale. Range 2 and 3 are subdivided according to the urgency of maintenance/intervention. In Germany CR scales run from 0 (good) to 4 (very poor). Each bridge component is assigned three ratings: one each for structural damage, traffic safety, and bridge durability [8]. Many documents point out that more durable structures have a longer service life and are much easier and cheaper to maintain [13].

Tabela 6. Vrednost stanja (CV), prema [20]
Table 6. Condition value (CV), after [20]

Defekti / *Defects*	CV
Bez procene / *No judgement*	0
Bez suštinske mane / *No meaningful defect*	1
Manji defekti koji ne izazivaju štete / *Minor defects that do not cause damage*	2
Srednji defekti koji izazvaju štete / *Moderate defects that could cause damage*	3
Ozbiljni defekti koji izazvaju štete / *Severe defects that cause damage*	4
Nefunkcionalni ili nepostojeći element / *Non-functional or non-existent element*	5

Konverzija iz vrednosti stanja (CV) u faktor stanja (CF) / *Conversion from the condition value (CV) to the condition factor (CF)*

CV	0	1	2	3	4	5
CF	0	10	7	4	2	1

Tabela 7. Faktor lokacije (LF) i težina (W), [19]
Table 7. Location factor (LF) and weight (W), [19]

Konstruktivni element / *Structural elements*	LF	W
Glavni elementi (grede, lukovi, stubovi)/ *Principal elements (beams, arches, piers)*	5	10
Poprečni elementi (ležišta, neseizmički uređaji, ploče) / *Transversal elements (bearing, non-seismic devices, slabs)*	6	9
Oporci, pritupni nasip, krilni zidovi / *Abutments, approach embankment, wing-walls*	7	8
Oporci i temelji stubova / *Abutment and pier foundations*	8	7
Nekonstruktivni elementi / *Non-structural elements*	LF	W
Hidroizolacija, kolovoz puta, dilatacione razdelnice / *Waterproofing, road pavement, expansion joints*	9	6
Kolovoz, parapeti, drenažni sistem, pristupi / *Pavements, parapets, drainage systems, accessories*	10	5

Tabela 8. „Zdravlje" mosta (MLIT, 2014) Japan, [1]
Table 8. Bridge soundness (MLIT, 2014) Japan [1]

Stanje / *Condition*	Opis / *Description*
1. Dobro / *Good*	Bez problema u funkcionisanju / *No problems in bridges functions*
2. Preventivno održavanje / *Preventive maintenance*	Bez problema u funkciji mosta, ali zahteva se preventivno održavanje / *No problems in bridges functions but preventive maintenance required.*
3. Rane aktivnosti / *Early action*	Mogući problemi u funkciji, potrebne rane akcije / *Possibility of problems in bridges functions, need for early actions.*
4. Hitne akcije / *Emergency actions*	Mogući problemi u funkciji, potrebna hitna intervencija *Possibility of problems or existing problems in bridges functions, need for emergency action .*

Table 9. NBI Rejting stanja (FHWA, 2012), [11]
Table 9. NBI Condition ratings (FHWA, 2012), [11]

Rating	Opis stanja / *Description*
9	Odlično stanje / *Excellent conditions*
8	Vrlo dobro stanje. Nisu zapaženi problemi / *Very good conditions. No problems noted*
7	Dobro stanje. Zabeležni manji problemi / *Good conditions problems noted. Some minor problems*
6	Zadovoljavajuće stanje.Elementi pokazuju manje znake deterioracije / *Satisfactory conditions. Structural elements show some minor deterioration*
5	U osnovi, povoljno. Svi primarni elementi su „zdravi", s manjim gubitkom preseka, naprslinama, odljuskavanjima ili podlokavanjima / *Fair foundation. All primary structural elements are sound but may have minor section loss, cracking, spalling, or scour*
4	Kritično stanje. Gubitak dela preseka, deterioracija sa odljuskavanjem ili podlokavanje / *Critical conditions. Loos of sections, deterioration spalling, or scour*
3	Ozbiljno stanje.Gubitak preseka ili deterioracija primarnih elemenata. Naprsline od zamora čelika ili smičuće naprsline u betonu / *Serious conditions. Loos of sections andor deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present*
2	Kritično stanje. Uznapredovala deterioracija primarnih elementa. Naprsline od zamora čelika ili smičuće naprsline u betonu ili podlokavanje izaziva pomeranje oslonaca, može iziskivati zatvaranje mosta do sanacije / *Critical conditions. Advanced deterioration of primary structural elements. Fatigue cracks in steel shear cracks in concrete may be present or scour may have removed substructure support. Unless monitored, it may be necessary to close the bridge until corrective action is taken*
1	Stanje „otkaza". Veća deterioracija ili gubitak preseka u kritičnim elementima ili jasna pomeranja. Most se zatvara za saobraćaj do sanacije / *„Imminent" failure Failed conditions. Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structural stability. Bridge is closed to traffic but corrective action may put it back in light service*
0	Stanje „otkaza". Van upotrebe / *Failed conditions. Out of service and beyond corrective action.*

Od osobite važnosti je način ocene stanja mostova i njihovih komponenti iako procena mosta započinje vizuelnim pregledom. U tabeli 8. prikazana je metodologija ocene stanja u Japanu, povezivanjem stanja i opisom akcija/interventnih mera. Da bi se obavio početni pregled i ustanovilo i vrednovalo svako stanje mosta, stvara se set izveštaja o pregledu mosta, korišćenjem tabele sa opisom stanja prema tabeli 9 koju je utvrdila FHVA [11]. Pokazatelji performansi za kontrolu i upravljanje kvalitetom mostova prikazani su u [27].

U COST Action TU 1406 definišu se pokazatelji performansi mosta: pouzdanost, dostupnost, održivost, sigurnost, bezbednost, zdravlje, okruženje, ekonomija i politika [28]. Terminološki kriterijumi bi trebalo da budu povezani sa aspektom performansi i podkriterijumima s ciljem [21] – bezbednost od neprihvatljivog rizika, u smislu povreda ljudi. Sigurnost sistema u vezi s vandalizmom i nerazumnim ljudskim ponašanjem. Ovaj problem se može rešiti analizom robusnosti mosta. Ekonomija razmatra odnos između troškova i vrednosti, a politika se odnosi na političko-administrativne i društvene potrebe.

Savremeni BMS-i uključuju bazu podataka mostova, sistem pregleda, procenu stanja, predviđanje budućeg stanja u eksploatacionom veku i planiranje održavanja objekta. Savremeni BMS-i imaju sledeće module: 1) baza podataka / inventar; 2) pregledi/inspekcija; 3) održavanje; 4) trošak životnog ciklusa; 5) model predviđanja oštećenja

The method of assessing the condition of bridges and their components is important. Table 8 shows the methodology for assessing the condition in Japan, by connection the condition and describing the actions. The bridge inspection report forum is created for initial inspection of determination of the baseline of every bridge condition by using general condition rating table 9 which was established by FHWA [11]. Performance indicators for bridge quality control and management is shown in [27].

In COST Action TU 1406 defining bridge performance indicators: reliability, availability, maintainability, safety, security, health, environment, economics, and politics [28]. The terminology criteria should be related to the performance aspect and sub-criteria [21]. Safety related from unacceptable risk in terms of injure to people. Security related to the safety of a system regarding to vandalism and destructive human behaviour. This problem can be solved by analysis of bridge robustness. Economics addresses the relationship between cost and value, and politics concerning political-administrative and social requirements.

Modern BMS includes a bridge database, an inspection system, a condition evaluation, a lifetime prediction of the future conditions of the structure and maintenance system planning. Modern BMSs have the following modules: 1) Database/Inventory; 2) Inspection;

– slabljenja svojstava za preostali vek trajanja postojećih mostova [24] i [29]. Većina poteškoća je povezana s definisanjem modela deterioracije, jer agencije za transport (u Srbiji Direkcija za puteve) nemaju pouzdane podatke o oštećenjima i brzini starenja i oštećenja (slično je i u svim ostalim državama).

U više radova može se pronaći uporedna analiza BMS-a u različitim zemljama, kao što su [2–6], kao i za metodologije pregleda i kriterijume za procenu [7]. Najšira razmatranja o sadržaju i primeni BMS u SAD i u svetu obuhvaćena su u knjizi Yaneva [30], koja može poslužiti za dublje razumevanje složenih problema u vezi s BMS-om.

6 ZAVRŠNE NAPOMENE I ZAKLJUČCI

Na osnovu svih ovih upoređivanja, mogu se uočiti razlike i sličnosti između odredaba pojedinih zemalja, što može koristiti pri inoviranju BMS-a u Srbiji, Bugarskoj i državama našeg regiona. Pri tome, treba imati u vidu sledeće:

- Napredak nauke s razvijenim determinističkim i probabilističkim pristupom upravljanju mostovima mora u potpunosti iskoristiti i jedno i drugo, u ravnoteži pogodnoj za specifične potrebe svake lokacije.
- Redovni monitoring stanja komponenti mosta u BMS-u omogućuje blagovremene intervencije, čime se obezbeđuju veća trajnost i upotrebljivost mostova. To se postiže optimizacijom troškova održavanja.
- Predloženi BMS treba da obuhvati modele celokupnog životnog ciklusa i alate za upravljanje kvalitetom i optimizacijske modele troškova/koristi povezanih s mostovima, što bi pomoglo u donošenju odluka institucijama koje upravljaju saobraćajem i mostovima. BMS je postao lako dostupan inspektorima i donosiocima odluka zahvaljujući napretku informacionih tehnologija [1].

Za smanjenje troškova održavanja, preporučuje se projektovanje integralnih mostova (bez dilatacija), a i sa integralnim pristupom tretirajući kompletan životni ciklus (od početka projektovanja do uklanjanja objekta), jer se time obuhvata i upravljanje objektima [4] i [6].

Procedura u BMS-u uključuje dva nivoa analize: nivo projekta (uzima u obzir svaki pojedinačni most) i nivo mreže (s obzirom na to što je most deo globalne putne mreže). Cilj je utvrditi prioritet intervencije, prema oceni stanja mosta na osnovu pregleda i kvantitativne ocene (rejtinga). Održavanje mreže mostova moglo bi se poboljšati definisanjem trendova deterioracije, pomoću modela životnog ciklusa, zasnovanih na performansama. Neophodna je adekvatna metodologija upravljanja mostovima, koja uključuje planiranje troškova održavanja ili rehabilitacije objekata.

Cilj redovnih inspekcija jeste direktno kontrolisanje stanja građevine i održavanje bezbednosti saobraćaja na zadovoljavajućem nivou. Ipak, upravljanje se zasniva na ekonomskim analizama i rangiranju po prioritetima, jer se neophodno raspoloživa sredstva koriste na najefikasniji način, budući da je budžet u svim državama ograničen. Koncept upravljanja objektima zahteva da minimalnim ulaganjima u praćenje ponašanja i popravke obezbedimo nesmetano korišćenje objekta u nekom vremenskom intervalu. Imajući u vidu strategije održavanja, dve krajnje pozicije jesu: sprovođenje održavanja čim se pregledima

3) Maintenance; 4) Life Cycle Cost; 5) Prediction model (Deterioration prediction in remain service life for existing bridges [24] and [29]. Most difficulties occur while developing deterioration models because transportation agencies have no reliable data about defects and rates of aging and damage. They are specific to every state.

In another paper we can find comparative analysis of BMSs in different country as in [2-6], and for inspection methodologies and evaluation criteria [7]. The widest considerations on the content and application of BMS in the United States and in the world are given in Yaneva book [30], which can serve for a deeper understanding of the complex problems related to BMS.

6 FINAL REMARKS AND CONCLUSIONS

The presented comparisons reveal differences and similarities between the provisions of individual countries, which can be used in the further development of BMS in Serbia, Bulgaria and the countries of our region. It should be borne in mind that:

- Science advances by deterministic and probabilistic reasoning and bridge management should take full advantage of both, in a balance suitable for the specific needs of every location;
- Regular monitoring of the condition of bridge components in the BMS enables timely interventions, which ensures greater durability and service-ability of bridges. This is achieved by optimizing maintenance costs; and that
- The proposed BMS should include life-cycle models, tools for quality management, and cost-benefit optimization models related to bridges, which would help decision-making institutions that manage traffic and bridges. BMS has become easily accessible to inspectors and decision makers thanks to advances in information technology [1].

It is recommended to design integral bridges, without expansion joints, and using an integral approach, comprising the complete life cycle (from the beginning of designing to the removal of the structure) because this includes the structural management [4] and [6].

The procedure includes two levels of analysis: the project level (considers every single bridge), and the network level (considering inserted in a global road network). The aim is to establish priority of intervention, according to the evaluation of bridge condition based on inspection and quantitative rating. Bridge evaluation starts with visual inspection. For bridge network maintenance could be improved by defining deterioration trends with performance-based life cycle models. An adequate bridge management methodology is needed, which includes planning the costs of maintenance or rehabilitation of structures.

The goal of regular inspections is to directly control the condition of the building and maintain traffic safety at satisfactory level. However, management is based on economic analysis and ranking by priorities because it is necessary to use the available funds in the most efficient way, since the budget in all countries is limited. The concept of structural management requires that minimal investments in behaviour monitoring and repair ensure an uninterrupted use of the structure in a certain time interval. When considering maintenance strategies there utvrdi potreba; održavanje ostvariti samo iz sigurnosnih razloga. Prva uslovljava češće popravke i zastoje u saobraćaju, a druga zahteva uravnoteženje troškova zbog kraćeg trajanja mosta, kako bi se izbegli veći troškovi održavanja [2].

U SAD, pored sinteze dokumenata iz njenih pojedinih država, sačinili su uporednu analizu evropskih i nekih drugih država u [8]. Ocenjujemo da bi Srbija i Bugarska, s ponekim modifikacijama postojećih BMS i po ugledu na neku od evropskih zemalja, mogle doprineti ekonomičnijem upravljanju mostovima. Takođe, preporučuje se uvođenje savremene metode praćenja stanja elemenata i mostova – nadgledanje „zdravlja" konstrukcije (SHM).

are two extreme positions: to carry out maintenance as soon as inspections identify the need, and to carry out maintenance only on safety grounds. The first requires more frequent repairs and traffic congestion, and the second requires balancing costs due to the shorter bridge life in order to avoid higher maintenance costs [2].

In the USA, in addition to the synthesis of documents from the states, a comparative analysis of European and some other countries [8] was conducted. We estimate that Serbia and Bulgaria, with certain modifications of the existing BMS and following the example of some of the European countries, would contribute to more economical management of bridges. Also, it is recommended to introduce a contemporary method of monitoring the condition of the elements and bridges - Structural Health Monitoring (SHM).

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APSTRAKT

UPOREDNE ANALIZE NEKIH SISTEMA ZA UPRAVLJANJE MOSTOVIMA

Radomir FOLIĆ
Doncho PARTOV

Sigurnost i funkcionalnost betonskih putnih mostova od posebnog su značaja za kontinuitet saobraćaja u različitim okolnostima, uključujući zemljotrese, poplave, kao i nakon udara broda ili vozila u njihove stubove. To je razlog što skoro sve države koriste Sistem za upravljanje mostovima (BMS). Ovi sistemi uključuju priručnike za inspekciju mosta, smernice za pisanje izveštaja, procenu stanja mosta i određivanje prioriteta za radove na održavanju ili sanaciji radi postizanja proračunskog eksploatacionog veka mostova. U ovom radu predstavljena je uporedna analiza nekih dokumenata iz određenih zemalja i udruženja, koji se odnose na BMS i njihove glavne komponente.

Ključne reči: betonski mostovi, sistem za upravljanje mostovima, pregledi, procena stanja, rejting mosta, deterioracija, modeli za prognozu, performanse, eksploatacioni vek

ABSTRACT

COMPARATIVE ANALYSIS OF SOME BRIDGE MANAGEMENT SYSTEMS

Radomir FOLIC
Doncho PARTOV

Safety and functionality of concrete road bridges are of a special importance for the traffic flow continuity in different circumstances including after earthquakes, floods, as well as after vessel or vehicle impact on piers. This is why almost all countries use Bridge Management Systems (BMS). They include the bridge inspection manuals, guidelines, report writing, bridge condition evaluation and determination of priorities (rating) for maintenance work or rehabilitation to achieve the design service life of bridges. This paper presents a comparative analysis of some documents of certain countries and associations, related to BMSs and their main components.

Key words: Concrete bridges, bridge management system (BMS), inspections, condition assessment, bridge rating, deterioration, performance, forecast models, service life