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SOFTWARE APPLICATION FOR OPEL CARS' MAINTENANCE MANAGEMENT

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***Abstract*—**Our application is based on a 3-tier database architecture composed by Presentation, Logic and Database layers. Though the Crawler module we extract relevant data from archive of orders with maintenance operations and spare parts. In this paper, we focus on Presentation layer, the topmost level of application by which users have directly access such as a web page or application GUI (graphical user interface). Through this layer the user ask for information, it communicates with other architectural layers in order to output, the text or graphical results. Showing users a bulk table of data is not always a good approach. Instead, this GUI shows especially graphic drawings of the data and diagrams. Using this representation of data in an open friendly interface the user is empowered with great understanding of the patterns that might occur on part assembly or dependencies between changing some parts and damaging others.

***Keywords*—**Database, Reliability, Data mining, SQL.

I. INTRODUCTION

THIS work is part of a broader application dedicated studying Opel cars' reliability that we developed. Previously we designed a 3-tier database architecture composed by Presentation, Logic and Database layers. In [1] we have implemented the Crawler module that extract relevant data from Microsoft Excel files and have conceived and designed the conceptual scheme of relational database, tables and relationships that that supports time analysis of defects cars.

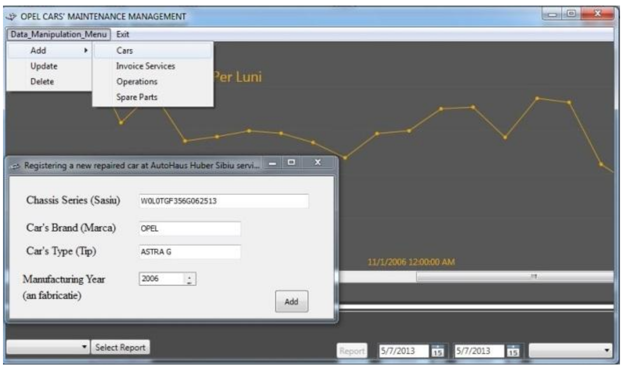


Fig. 1. The user friendly input interface

Although the main purpose of our software application was the automatic processing of invoice services and highlighting various analyzes about cars' reliability and maintenance, we have additionally built a module by which to allow inserting / modifying / deleting individual data from the database (taking care for ensuring consistency) (see Figure 1).

In this paper we present our developed software application for studying OPEL cars' maintenance management. We implemented in Microsoft Visual Studio 2012 (C#), .NET Framework, using Microsoft SQL Server 2008, a Data Visualization Module able to show graphical results about spare parts, operating mode, and supports time analysis of defects cars. We focus on Presentation layer, the topmost level of application by which users have directly access such as a web page or application graphical user interface. Through this layer the user ask for information, it communicates with other architectural layers in order to output, the text or graphical results. Showing users a bulk table of data is not always a good approach. Instead, this GUI shows especially graphic drawings of the data and diagrams. Using this representation of data in an open friendly interface the user is empowered with great understanding of the patterns that might occur on part assembly or dependencies between changing some parts and damaging others. We nominated several features of our application:

- comparative statistics on years of relevant mechanical components that were repaired
- quantifying the frequency of defects' occurrence on certain types of cars and vice versa,
- which certain type of car get parts with the lowest reliability
- identifying the operations frequently carried out to a certain car for a well-defined period of time

At present, the database is customized to serve at AutoHaus Huber SRL Sibiu, OPEL dealer, but with small modifications it could be extended to any auto service from Romania or outside.

With the help of this software application, based on huge history information from any car service, the manager obtains an extremely agile understanding of the common malfunctions that a car system can suffer and even point out to parts producer, patterns that appear in their design ("*Business intelligence*", one of the key factors in planning marketing strategies). This will improve the quality of spare parts production through focusing on specific directions depending on the geographic area, the infrastructure of the region, environmental conditions, characteristics of fuels, etc.

The present application is extremely useful because the processing and interpretation of data extracted obtain a fairly accurate understanding of the common faults that may occur in operating a motor vehicle, may determine the causes of breakdowns, can identify abnormal wear.

The organization of the rest of this paper is as follows. In section II we shortly review the challenges regarding the cars' reliability operating in Romania, emphasizing on OPEL vehicles. Section III represents the centerpiece of this work and describes the Relational Database Management System. It starts with presenting the main features of SQL language, then it review the most used database queries for highlighting the behavior in operating of OPEL cars' and it finishes detailing the Presentation layer concept: the user guide and Data Visualization Module. Section IV graphically illustrates the most important experimental results that we obtain with our application. Finally, section V suggests directions for future work and concludes the paper.

II. RELIABILITY

The reliability domain is extremely large. When discussing about cars even we have to split the diagnosis in two: the electronic system reliability and the mechanical system reliability. Therefore, in this paragraph we first intend to explain some basic concepts about reliability and then to focus on some challenges in terms of vehicles' reliability, mainly of mechanical's system, exemplifying with OPEL cars.

A. Basic concepts

The *availability* of a system at time t is the probability that the system is operating correctly at time t. The *reliability* of a system at time t is the probability that the system has been operating correctly from time zero until time t [2]. However, many times reliability is less appropriate metric. In the event of a catastrophic system failure car, reliability is a less useful metric than availability. *Maintainability* is the probability that maintenance of the system will retain the system in, or restore it to, a specified condition within a given time period. Reliability, availability, maintainability (RAM) are fundamental features of any system and the RAM performance should be optimized to get the best value from the engineering design and enable a system to meet the service expectations.

After duration and mode of occurrence there are known three kinds of faults and errors:

- *Transient* (due to electronics circuits),
- *Permanent* (due to physical wear-out, fabrication defects or design bugs)
- *Intermittent.*

The complicate design of technical systems, in order to assure high performance may represent, in some cases, even their degradation sources. In these conditions, it can reach a critical level of development and improvement of systems, in which the recovery time would equal the production of new products. Avoiding such situations is the basic principle of terotechnology which involves a continuous improvement in reliability in parallel with technological development [3].

B. Challenges in the vehicles reliability

Regarding cars' reliability, the points of views converge for both the customers and manufacturers. The first want that their car to be safety (or ask how often it needs repairing) and liveness, despite the possibility of faults, and in such case, how much it will cost them to put right. Thus, as more reliable the car is as more satisfied are them. On the other hand, the manufacturers are interested to produce reliable cars in order to thank the customers, therefore could ask for a higher price or will attract more customers.

However, the cost of the operations, maintenance, and support of vehicles is quite large due to a reduced cars' reliability. One of the reasons for the difficulty of managing cars' costs is due to the complexity of predicting the performance and reliability of a vehicle early in the design cycle, over the vehicle's life, or the car usage over time [4]. Nowadays mathematical and computer science researchers face with challenges of predicting vehicle's reliability and performance, reliability-based design optimization, condition-based maintenance, methods of handling large data sets and models (*data mining*). A major challenge is to find accurate methods to assess vehicle reliability using modeling and simulation. Reliability is a highly complex field, involving many different physics-of-failure, including fatigue, thermal stress, corrosion, and erosion. Reliability is based on stochastic methods because involves uncertainty in the input data. The evaluation of cars' reliability in many different physics-of-failure is a huge computational challenge.

In the next sections we focus on handling these large data sets in order to emphasize the most important results regarding to cars' reliability and maintainability from AutoHaus Huber Sibiu.

Whatever invests in order to ensure the reliability of a complex system as the car cannot achieve an ideal reliability, i.e. a system that basically do not degrade over time. It is required accurate knowledge of the real level of reliability as well as existing operating conditions (in Romania) [5], so that, according to them, to establish lasting operation without failures, periods for maintenance. Due to operating conditions, the car manufacturers differentiate the period in which they perform maintenance revision, depending by country, geographic area, etc.

Next, we give some examples regarding OPEL cars' reliability. To reduce friction from piston group it is used only oil provided by the manufacturer (General Motors). Through the viscosity controls the friction regime and the lubrication one. Using another type of oil leads to increasing the power losses by friction, increasing the fuel consumption and to insufficient cooling of parts. Thus, it is avoided high oil consumption and the intervention on engine for at least 500,000 km for repair and overhaul. Diesel fuels' composition exerts a very important influence on engine reliability and durability, as occurs both in the process of mixture formation and the combustion process. Thus, diesel quality affects the propensity to rough operation, the startup and operation of the engine. Diesel fuel provides lubricating role for injectors and injection pumps. Using the poor quality Diesel injectors lead to blocking them and of injection pump elements. Also, due to very short period of the ignition delay, it cannot penetrate the entire volume of chamber; auto-ignition and combustion will take place near the injector. Submission of soot and tar on the exhaust system or exhaust gas recirculation valve is another major cause of defects in Opel cars. Because most of the air is not used properly in the combustion process, the economy of engine is reduced and the smoke into the exhaust flue increases. As long as the ash remains in suspension, the risk is reduced for deposit formation, but this risk increases significantly when the ash become viscous because it touch the colder areas of the engine, intake valves respectively. The basic factors of operating conditions that influence reliability and durability are the road conditions, weather conditions, operating regime, driving skills, maintenance quality and vehicles' quality repair. Road conditions and its profile influences the movement speed of the vehicle, the size, frequency and nature of tasks that act on the running parts, suspensions, bodyworks and transmissions aggregates, engine operating conditions, the number of connection and disconnection of the clutch, braking and steering systems, quality and physical properties of dust, maintenance difficulty and driving.

III. RELATIONAL DATABASE MANAGEMENT SYSTEM

A. The main features of SQL

In practice, creating and using relational databases requires a standard language that allows these operations. Thus, it was developed a relational programming language as software that assists the implementation of databases. IBM has made in the middle of 1970s the first implementation of the SQL (Structured Query Languages) followed by the first commercial version of the company's Relational Software (known today as the Oracle). Today SQL is fully standardized and is recognized by theAmericanNationalStandardsInstitute (ANSI).

The SQL commands can be classified in 5 categories [6], [7]:

1. Query commands. Allows the retrieval of lines stored in tables according with certain requirements. SELECT command is specific to this class.
2. Data Manipulation Languages. Controls the table content. INSERT, UPDATE and DELETE are specific to this class.
3. Data Definition Languages. Establishes database structure and table components with the help of CREATE command, alter or delete structure with ALTER, RENAME, DROP or TRUNCATE.
4. Transaction Control. It determines transactions completion (the changes in database become permanent - COMMIT), or it cancels the latest changes (ROLLBACK) or implements check pointing mechanism by which can return, canceling the changes occurring after this point (SAVEPOINT).
5. Data Control Language. Allows defining and changing user rights on the database (GRANT - providing rights and REVOKE - removing rights).

B. Database queries for highlighting the behavior in operating of OPEL cars'

In this paragraph we present the Database queries for highlighting the behavior in operating for a determined period of time of OPEL cars'. With the help of queries we intend to emphasize common patterns present in car service and parts production failure.

For accessing data in the database layer, we need to make some queries and return appropriate data. The following tables are currently mapped in our database: *Autoturism, Comanda, ListaOperatii, ListaPiese, Piesa.* Further, we exemplify some queries that we used in our application.

- Chassis identification in database in order to incorporate a new record in the cars' table (“Autoturism”).

```
SELECT * FROM Autoturism WHERE RTRIM(sasiu)='W0L0TGF356G062513'
```

- What is the number of operations performed every day and how much cost the workmanship? Grouping records by date/time field in a predetermined range and ordering low revenues. Using aggregate functions.

```
SELECT dataCreareFisa, COUNT(*) as total_manopera, SUM(oraTotalLucrate*oraTarifara) AS suma_incasata_manopera FROM comanda WHERE (dataCreareFisa>'2009-1-1') AND (dataCreareFisa<'2010-1-1') GROUP BY dataCreareFisa ORDER BY suma_incasata_manopera DESC
```

- Ensuring integrity restrictions (deleting spare parts that appear in commands that do not exist in “Comanda” table) by using nested queries.

```
DROP FROM ListaPiese WHERE idComanda NOT IN (SELECT nrComanda FROM comanda);
```

- Based on the relations established after normalizing of database may associate related tables in a formal way, easy to use, so that to combine data from multiple tables within the same query, while maintaining the flexibility to include only the interesting information for user. To do this, we used relational operators such as intersection, difference and Cartesian product of two or more tables.

```
CREATE TABLE Temp(idPiesa bigint, piese_total numeric)

INSERT INTO Temp (idPiesa,piese_total) SELECT idPiesa, COUNT(*) AS piese_total FROM ListaPiese GROUP BY idPiesa ORDER BY piese_total DESC

SELECT TA.idPiesa, TB.denumirePiesa, TA.piese_total FROM Temp AS TA INNER JOIN Piesa AS TB on TA.idPiesa=TB.idPiesa
```

```
DROP TABLE Temp
```

Due to the huge amount of information stored, one problem occurred in this kind of data queries is the fact that it takes extremely long time to iterate (few seconds for 15 Mbytes of data). In C#, every table has its Table Adapter class (e.g. *AutoturismTableAdapter*) that contains specific methods used for accessing database.

```
public partial class AutoturismTableAdapter :
                              global::System.ComponentModel.Component{…};

this._adapter.InsertCommand.CommandText = "INSERT INTO [Autoturism] ([sasiu], [marca], [tip], [anFabricatie]) VALUES (@p1, @p2, @p3, @p4)";

this._adapter.DeleteCommand.CommandText = "DELETE FROM [Autoturism] WHERE (([sasiu] = @p1))";
```

This mechanism produces an additional level of indirection of databases operations that ultimately lead to high latency. This slow iteration remains an open problem. As further development method we must analyze more performing search algorithms of unstructured data and faster access to the database using *data mining* techniques.

C. The Data Visualization module

As we stated before, this section presents the Presentation tier (as known as *Frontend*) of previously started 3-tier database architecture [1]. This layer (implemented here in *Data Visualization Module*) is the topmost level of application by which users have directly access such as a web page or application GUI. Through the Presentation tier the user / client ask for information such "*Get the most replaced component*?" or "*Which is the most performed operation to a certain car*?" It communicates with other architectural tiers (*Logical* and *Database* – implemented by *Crawling* and *Database Modules*) in order to output, finally, the text or graphical results [8].

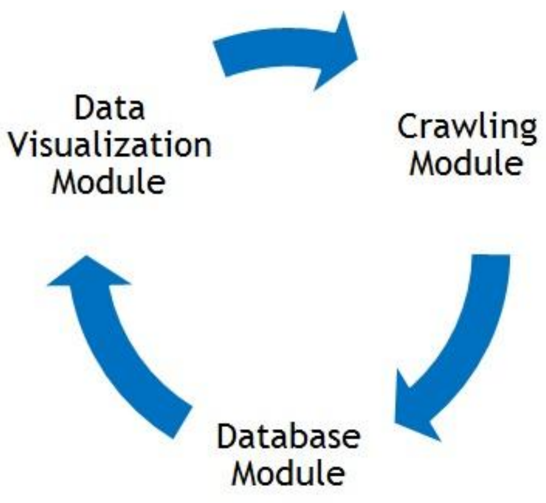


Fig. 2. The dataflow between 3-tier architectures modules

The diagram from Figure 2 points out the relationships between modules (uninterruptible chain) for providing the user requested information. For example, Data Visualization Module requires information to illustrate the amount of certain categories of spare parts and notifies that has no data to display. In this moment Database Module requests information from Crawling Module, etc. As we can see, the Crawling Module offers the interface to the real data, present on computers of OPEL service station (extracted from invoice services). This layer has the task to gather this data, indexing it in and then present it to the next module, the database.

For ordinary users data in a raw format (unformatted data, unstructured, unorganized) means headaches, and showing this data extensively proves nothing, even creating confusion. That's why, for a higher impact on the subject special graphic libraries needed to be created or extended, because it is well known that "*A picture is worth a thousand words*!" Despite the fact that the design is appealing it also brings the user the possibility to "grab" graphs and navigate them for a better understanding and take the proper decisions.

Our application provides a user friendly output interface (see Figure 3). First, you can select the range time for study. The next step is to choose whose is applied the analysis: individual or general. If we consider individual study we must know the Vehicle Identification Number (VIN) - field "sasiu" in our "Autoturism" table that is a dedicated coding. In the following, we make a short overview about this important key from vehicle domain.

VIN is a unique number identifying a vehicle. Before 1981 there was no standard to describe this number and the manufacturers have used different formats. Today, VIN consists of 17 characters, numbers and letters, which do not include the letters I, O and Q [9], [10]. VIN consists of the following sections:

- WMI (World Manufacturer Identifier) – vehicle manufacturer region (characters 1-3).
- VDS (Vehicle Descriptor Section) – characters that identifies the type of vehicle, information about the model and body style. In practice, each manufacturer decides how to use this number on your own (characters 4-9).
- VIS (Vehicle Identifier Section) – characters that identifies a unique vehicle. This includes information on installed equipment and engine data (characters 10-17).

However, for a time analysis, we consider quantifying the frequency of defects' occurrence on certain types of cars (general view) and vice versa, by introducing a certain type of car to get parts with the lowest reliability (On what cars occur the most defects?). Other facilities of our application are:

- Identifying the operations frequently carried out to a certain (all) car(s) for a well-defined period of time by choosing "*TopOperatii*" option, or determining how many times was performed a certain operation.
- Identifying the most commonly replaced parts to a certain (all) car(s) by choosing "*DevizRaportMod*" selection, see Figure 3.

- Time analysis of revenues. Financial approach of company based on the repaired cars (see Figure 4).

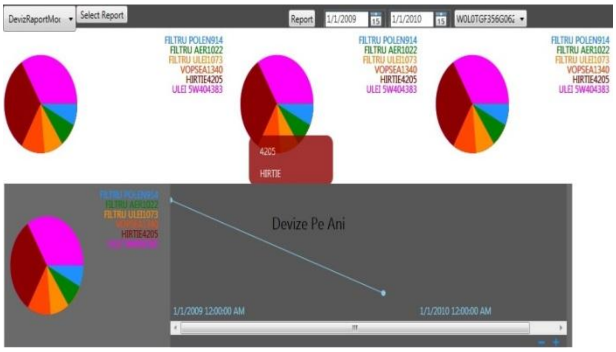


Fig. 3. Identifying the most commonly replaced parts to a certain car

Fig. 4. The revenues from year 2009

IV. EXPERIMENTAL RESULTS

One of the main features of our developed application is flexibility. We may extract a lot of interesting statistics very helpful for mechanical engineer or manager. By highlighting common patterns present in car service and parts production failure, and through their intelligent analysis may result important information regarding to cars' reliability and maintainability. Experimental research was to study the behavior in operating a well-determined period of time of Opel cars and data collection from invoice services documents.

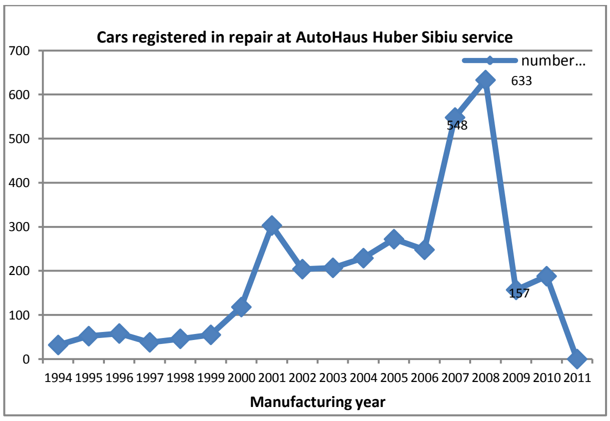


Fig. 5. Distribution of repaired cars on manufactured year

An interpretation that we can give the graph from Figure 5 is that cars produced in 2008, namely OPEL (as we can see in Figure 6), shows the lowest rate of reliability.

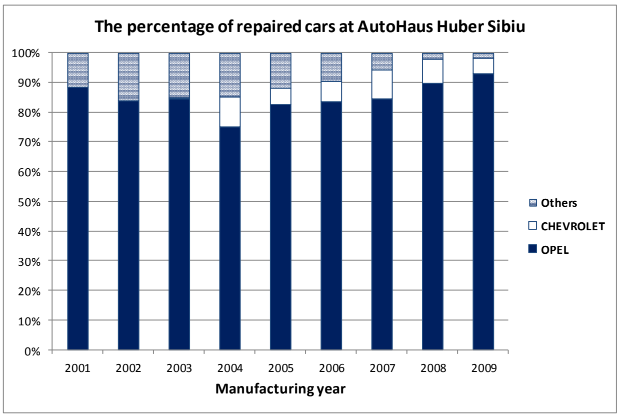


Fig. 6. Statistics of repaired cars on brand

In average, on the analyzed period, between 2001 and 2009, 85.5% of the repaired cars at AutoHaus Huber Sibiu were OPEL, 6% were CHEVROLET and 8.5% were others (26 brands).

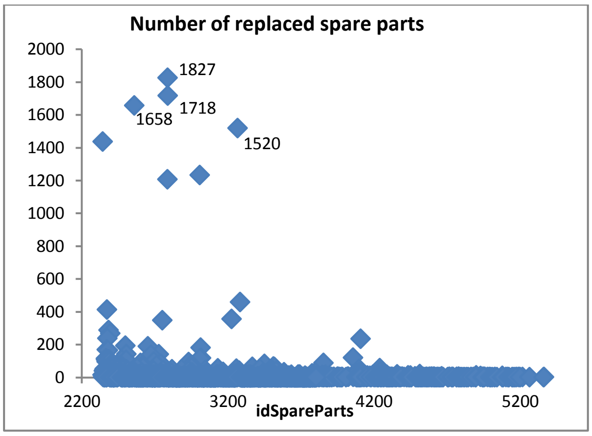
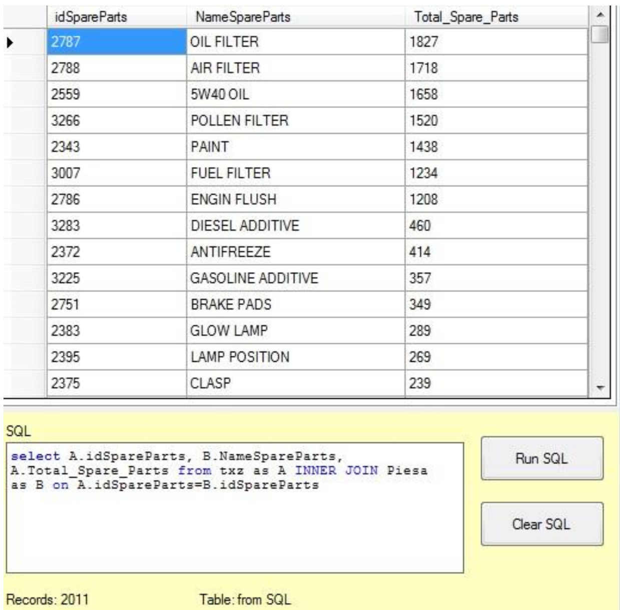


Fig. 7. The distribution of replaced parts (statistical view)



idSpareParts	NameSpareParts	Total_Spare_Parts
2787	OIL FILTER	1827
2788	AIR FILTER	1718
2559	5W40 OIL	1658
3266	POLLEN FILTER	1520
2343	PAINT	1438
3007	FUEL FILTER	1234
2786	ENGIN FLUSH	1208
3283	DIESEL ADDITIVE	460
2372	ANTIFREEZE	414
3225	GASOLINE ADDITIVE	357
2751	BRAKE PADS	349
2383	GLOW LAMP	289
2395	LAMP POSITION	269
2375	CLASP	239

SQL

```
select A.idSpareParts, B.NameSpareParts,
A.Total_Spare_Parts from txz as A INNER JOIN Piesa
as B on A.idSpareParts=B.idSpareParts
```

Run SQL
Clear SQL
Records: 2011 Table: from SQL

Fig. 8. The distribution of replaced parts (SQL view)

Figure 7 illustrates distribution of all replaced spare parts for whole analyzed period. As we can notice many spare parts have been replaced a few times but some of them very often. In figure 8 it can be seen the name of frequently replaced components.

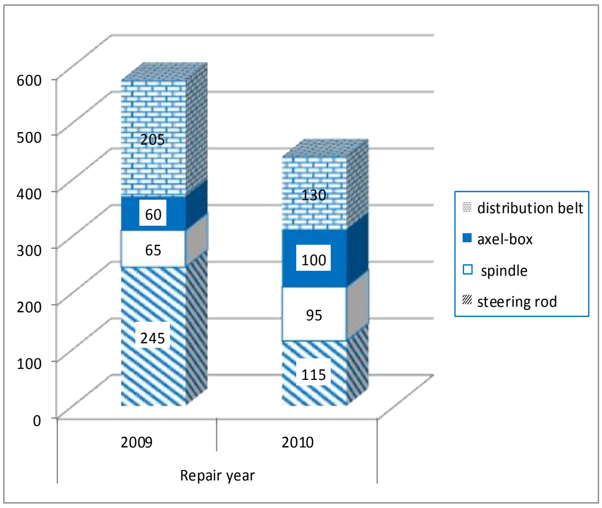


Fig. 9. Comparative statistics on years of relevant mechanical components that were repaired

The information from figure 9 may be correlated with the roads degradation in Romania, which influences among others the engine operating conditions, the number of connection and disconnection of the clutch, braking and steering systems.

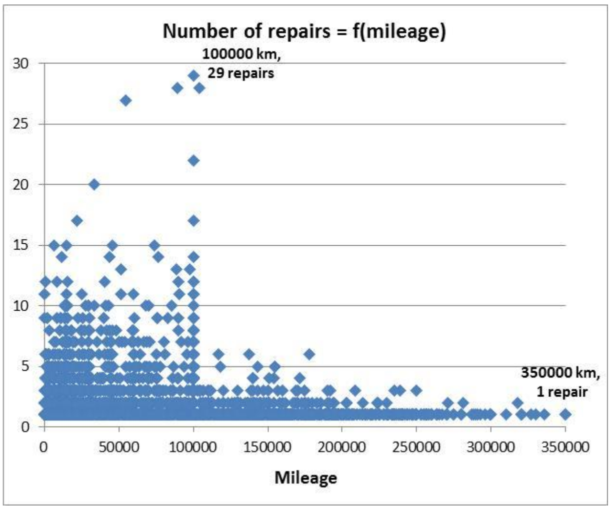


Fig. 10. Statistics about cars reliability

The chart above exhibits the number of repairs required by cars registered at AutoHaus Huber Sibiu depending on the mileage. Some cars are very reliable; they ran almost 350 thousands of km without requiring a major operation whilst there are others that were repaired 29 times until they traveled for 100 thousands of km.

V. CONCLUSIONS AND FURTHER WORK

In this work, we present our developed software application (written in Microsoft Visual Studio 2012 C# and Microsoft SQL Server 2008) for time analysis of defects cars, studying OPEL cars' reliability based on a relational database. Based on laborious database SQL queries and with the help of open friendly interface our application shows especially graphic drawings of the data and diagrams. This information provide a fairly accurate understanding of common faults that occur in operating a motor vehicle, determine the defects and causes of breakdowns, identify abnormal wear and even suggests the optimization solutions in the operating conditions from Romania.

As future work, we intend to create a profile, a reliability index, for each existing vehicle in our database in order to predict possible failures based on its history. We want to develop an assisted approach of reliability study, followed by a parameterized Computer-Aided Design (CAD) modeling, which uses as parameter's values the Excel tables resulted from the reliability study. Identifying of defects and their causes in the existing operating conditions can lead to redesign and CAD simulation of commonly replaced parts in order to increase vehicle's maintainability. Based on retrieved information at these stages we plan to tackle further.

REFERENCES

[1] L. Roman, A. Florea, N. Cofaru, “Implementing a relational database to survey cars' reliability exploited in Romania”, Annual Session of Scientific Papers - IMT Oradea 2013, submitted for publication.
[2] D.J. Sorin, “Fault Tolerant Computer Architecture”, Morgan and Claypool Publishers, 2009.
[3] T. Nagy, M.A. Stănescu, N. Turea, D. Dima. “Reliability and tero-technology of vehicles” (in Romanian), Vol I, “Transilvania” University of Brasov, 1999.
[4] D.A. Lamb, D. Gorsich, D. Krayterman, K.K. Choi, E. Hardee, B.D. Youn, D. Ghiocel, “A method to predict the reliability of military ground vehicles using high performance computing”, 25th Army Science Conference, Nov 27-30, 2006, Orlando, FL, USA.
[5] R. Negrilă, “Study of influence factors on the reliability of operating vehicles in order to optimize maintenance activity”, PhD Thesis (in Romanian), “Transilvania” University of Brasov, Faculty of Mechanical Engineering; 2005, Romania.
[6] M. Chaple, “Microsoft SQL Server 2008 for Dummies”, John Wiley & Sons, 2009.
[7] B. Syverson, J. Murach, “Murach's SQL Server 2008 for Developers”, Mike Murach Associates Inc., 2010.
[8] A. Tarhini, “Concepts of Three-Tier Architecture”, 2011, http://alitarhini.wordpress.com/2011/01/22/concepts-of-three-tier-architecture/ .
[9] http://www.mitchellsupport.com/ondemand5/VIN/VIN.pdf (accessed 10 April 2013)
[10] M. Olschimke, “Dealing with Vehicle Identification Numbers (VIN) #Data Quality”, 2012, http://www.olschimke.eu/2012/08/02/dealing-with-vehicle-identification-numbers-vin-data-quality/ (accessed 05 April 2013)