Strategic Database Modelling for Enhancing Firefighter Station Operations

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Abstract

Nowadays, an enterprise cannot function effectively or make informed business decisions without access to and use of business data. Business data provides information that supports strategic decision-making for entrepreneurs and all other employees within the organization. Therefore, this paper aims to demonstrate how strategically defining information requirements, and subsequently database modelling, supports business operations. Accordingly, the research methodology for this paper involves analysing a case study focusing on a specific fire department. Through the case study, the information requirements are identified and used to create a database model. Based on the modelling and creation of the database, the identified information requirements are analysed and discussed in the context of operational improvements for the firefighting station.

Introduction

Making superior strategic decisions ahead of the competition in today's challenging and competitive market is essential to contemporary, high-quality business operations. According to Williams (2023), generally, strategic management is crucial for effective decision-making, enabling organizations to align resources, anticipate risks, and implement strategies that provide a sustainable competitive advantage in dynamic markets. Measures like revenue growth, market share, customer satisfaction, and operational efficiency can be compared to predetermined strategic goals and objectives to help organizations assess the success of their strategic management initiatives and make data-driven decisions to optimize their business performance (Rohm, 2000). Therefore, organizations may determine where their strategic initiatives are succeeding and where they might need to modify their strategy by monitoring important indicators like sales revenue and client acquisition expenses (Rohm, 2000; OneStrategy.org, 2021). Accordingly, organizations can remain adaptable and make knowledgeable decisions that promote development and success by accessing this invaluable data.

Therefore, data management remains a crucial topic in today's academic and practical circles (e.g. Lukyanenko, 2024; Li and Smith, 2024; Pansara, 2021). Stakeholders everywhere are emphasizing the management and control of data more and more as it becomes a global asset. The world is becoming more digitally networked, which increases the demand for collaborative systems that enable numerous actors to work together inside a single framework for exchanging information, knowledge, and experience. Adopting a uniform approach to data, such as a data model (Geiger, 2009), helps improve coordination and lower the risks of fragmentation, which could otherwise be negative. It is especially significant for some industries during critical times, such as humanitarian emergencies (Marcucci et al., 2023). According to Geiger (2009), the data utilized inside an organization is represented from a business viewpoint by the business model, also known as a conceptual or data model. It includes information-related business standards and operates without regard to procedural, technical, or organizational limitations. As a result, the organization only keeps one business data model current at any moment (Geiger, 2009). An entity-relationship diagram (ERD) is a common visualization of this concept, usually depicted in at least a third normal form (Geiger, 2009). Relationships and referential integrity have been used to enforce business standards, preventing data redundancy (Geiger, 2009). However, poorly defined informational requirements can disrupt data models and hinder the further development of databases, which, in turn, obstructs effective strategic decision-making. Author Courtney (2001), in his work, highlights that poorly defined information requirements in decision support systems situations can lead to requirements for databases that differ significantly from those used in operational environments. Therefore, Courtney (2001) advocates for relational database usage and flexible query languages to address the complex and dynamic nature of decision-making in these settings.

Accordingly, this study sought to investigate the strategic development of a database model suited to particular firefighting demands by defining critical informational requirements, given the necessity to evaluate the relevance of a database model for firefighter station operations. To do this, we created a database model that matched and studied a firefighter station in Croatia. Our findings imply that the deliberate creation of data might improve the functioning of firefighting stations, especially when making decisions. We address the study limitations and suggestions for further research in this research area.

Therefore, this paper is organized as follows. After the introduction, the second section outlines the theoretical framework, which highlights key concepts for assessing the strategic significance of database modelling in firefighter station operations. The third section explains the methodology, followed by the fourth section, which presents the study's findings. The fifth section provides a brief analysis based on those findings. Finally, the conclusion includes closing thoughts, a summary of the study's limitations, and recommendations for future research.

Theoretical background

Data management

Decision-making is the cognitive process and behavior of selecting one course of action or choice from a range of options to meet a goal or solve a specific issue (Savioni et al., 2023). Daily, people and groups, such as governments, organizations, and other entities, encounter different circumstances where decisions need to be made (Abubakar, et al., 2019). Within the organizations, there are three tiers of management: operational, tactical, and strategic, each needing the appropriate data at all times (Rao, 2022) for obtaining an efficient decision-making process. Namely, the process of making decisions includes examining, assessing, and selecting the most suitable course of action or choice based on available data, information, and factors (de Andreis, 2020). Therefore, modern organizations cannot operate effectively or make business decisions without data on their performance and usability.

Data exists in an unprocessed state and lacks inherent significance beyond its mere existence (Bellinger, Castro, and Mills, 2003; Ackoff, 1989). It can take on various forms, regardless of its usability, and is best known by the term "spreadsheet" in computer terminology (Bellinger, Castro, and Mills, 2003; Ackoff, 1989). Data transforms into information when connected by a relational association by giving it significance (Bellinger, Castro, and Mills, 2003; Ackoff, 1989). This 'meaning' is not necessarily significant, but it could be. In computer terminology, a relational database can retrieve information from the data stored within it (Bellinger, Castro, and Mills, 2003; Ackoff, 1989). Interpreting data results in the generation of information, which is essentially a message that gives meaning to the data's context (Chen et al., 2009). Information provides updates and forms the foundation for business decision-making. Hence, the significance of information quality lies in its precision, pertinence, comprehensiveness, and promptness (Lee et al., 2002; Ballou and Pezer, 1985) for enhanced decision-making. Knowledge is a structured collection of data and information essential for decision-making (Croatian Encyclopedia, 2013; Stenmark, 2001). According to Stenmark (2001), knowledge may be explicit or exist in an implicit form. Furthermore, knowledge can exist on both an individual and collective level (Spender, 1998).

The exponential increase in the volume of data organizations are utilizing (Akhtar, 2023) stresses the importance of knowing the optimal way to store data to enhance efficiency and decision-making. The database represents an organized data set that can improve organizational work, enhance work continuity, and track data analysis (Desamsetti, 2020; Desamsetti, 2016). According to Oracle (2021), an organized collection of data or information, usually kept electronically in a computer system, is called a database. Similarly, author Akhtar (2023) defines a database as a long-term data collection integral to an information system. Also, the database management system is typically used to manage databases. Additionally, information, database management systems, and applications are all included in the phrase "database system" (Oracle, 2021).

Relational and non-relational database management systems are the two categories of database management systems (Akhtar, 2023). According to Akhter (2023), relational database management systems use a specified database schema to maintain the relational data model. Every table or relation in the database is identified by a unique name and has a fixed number of attributes (columns) with specific data types that remain constant (Akhter, 2023). Every row in the table represents a distinct entry (Akhter, 2023). According to Akhter (2023), these database management systems employ a variety of database languages, primarily the widely recognized Structured Query Language (SQL), to carry out diverse operations on the data contained in the tables. Conversely, unlike relational database management systems, non-relational database management systems usually do not include a SQL interface and do not rely on a relational data model. Although NoSQL databases have existed for a long time, the word was first used in 2009 when new systems were created to meet the growing demands of DBMS, such as fault tolerance, scalability, and Big Data (Padhy, Patra, and Satapathy, 2011; Akhter, 2023).

Data management importance in firefighter stations

The safety and well-being of the community a firefighter station serves are directly impacted by its efficacy. Having a comprehensive database can significantly enhance firefighter station's efficiency and streamline procedures. An effectively designed database should be able to gather and organize various data types, such as incident reports, equipment maintenance records, personnel information, and resource allocation (Molina-Pico et al., 2016; Basari et al., 2010; Ma & Qian, 2008). One crucial function of a database is its ability to oversee and control incident data. It is essential for analysing the firefighter station's response trends, pinpointing areas for improvement, and effectively distributing resources (Ma & Qian, 2008).

City, county, and municipal firefighting communities are the three categories into which local self-government bodies organize their firefighting operations. The Statute, the cornerstone of every firefighting association, governs the organization and internal arrangements, which must comply with Croatian laws and regulations (Firefighting Act, 2022).

The city or municipality's firefighting community is the appropriate body for advancing and growing firefighting only inside its borders. The volunteer firefighting society is established by the laws and regulations of the Republic of Croatia, and their primary task is the operational readiness of volunteer firefighters, performing firefighting duties such as going out for interventions, working with youth and children, going to competitions and carrying out all activities that support the promotion of firefighting in the local self-government unit, but also more widely, such as going to international competitions or going to the Firefighting Olympics (Firefighting Act, 2022).

The Croatian Fire Association is a central state office tasked with promoting and representing the interests of firefighting throughout the country. It coordinates the existence and operation of specific firefighter stations and is essential in firefighting development. According to the Firefighting Act (2022), the Croatian Fire Association is responsible for several primary tasks, including:

1. Proposing the establishment of the National Strategy for Firefighting Development, the Program of Activities for the Implementation of Special Fire Protection Measures, and the Design of the Firefighting System in the Republic of Croatia.

2. Encouraging the development of the operational aspect of firefighting and improving the conditions of fire protection intervention forces.
3. Updating the database, registers, and other digital innovations in business, ensuring the protection and security of the Central Information and Communication System while maintaining records of firefighting organizations, units, and firefighters.
4. Promoting and facilitating the procurement of firefighting equipment and creating analyses and proposals to improve firefighting interventions for Public Fire Departments.

Having a thorough understanding of the operational procedures and information requirements at the firefighter station is crucial when developing a database (Minsky, 1974). Analyzing data flow and identifying parties, such as emergency calls, dispatched units, and incident reports, is part of this process. Hence, when developing a database for a firefighter station, it is crucial to consider various facets of the organizational functions, including resource management, incident reporting, and fire alarm response (Picó et al., 2016).

Methodology

The research methodology used in this paper involved analysing a case study focused on a specific firefighter station. The firefighter station personnel collected crucial information for the case study, including internal firefighter station statistics. By using the SQL programming language and Microsoft Access, a database model was created based on the obtained data.

The first step in studying the chosen firefighter station is to identify and characterize the issues that will lay the foundation for establishing the information requirements for database model development.

In the next step of creating the conceptual model of the database, the entities and associated attributes necessary for the creation of the database are defined by the pre-defined information requirements. Furthermore, the Entity-Relationship model is defined in which the associations between the entities are established. Accordingly, the relational model (relational scheme) is created based on the Entity-Relationship model.

After creating the relational schema, the last step of data modelling and creating tables with the help of the SQL programming language begins. The first step of creating a database in this phase is creating tables with the help of created relational schemas. Tables are created in SQL using the CREATE statement. In the next step, using SQL programming language, all the data has been inserted within every column (attribute) of each table (relation) with the help of the SQL INSERT INTO statement. To fulfil each information requirement, we used a SELECT statement in the SQL programming language.

Results

It is challenging to recruit and attract new members for a range of extracurricular activities and pastimes, including firefighting, because the lives of individuals are so busy these days. Therefore, the first issue resulted in the first information requirement as follows: (1IR): *"How many members are registered in a certain firefighter station in 2023?"*.

Additionally, the problem of operational forces in the firefighting units comes after the previously mentioned issue of a shortage of free time. Accordingly, two information requirements arise: (2IR): *"Which operational members have a valid medical examination in 2023?"* (3IR): *"What is the number of operational members of*

the firefighting community?''. The ability of the firefighting units to intervene will be assessed using these two information requirements.

Moreover, the issue of regularly checking the ownership and existence of personal equipment in the firefighter station has induced the next information requirement: (4IR): *"Which personal equipment belongs to Fire Department 475?".* Additionally, the example of this information requirement will help when purchasing insufficient equipment. Therefore, all operational firefighters will be ready in an emergency.

Each voluntary firefighting unit has its structure. In particular, the Fire Association is managed by a certain number of people assigned to a particular function. To obtain information about the functions within the organization in an easier and faster way, an information requirement that would enable users to find their way around and find the responsible persons and their functions within each board of the association has been set as follows: (5IR): *"Which function falls under which committee of the firefighting community?''.*

Another observed issue is the interest of young people and children in firefighting. Therefore, the following two information requirements have arisen: (6IR) *"Which members are the leaders of the children's club?''* and (7IR) *"Which members of the children's club have participated in more than three competitions in the competition season 2023?''* have been proposed. Accordingly, the numerical state of leadership functions in association, the children and young people's interest in firefighting, and the motivation of the leadership will be investigated by those information requirements.

To give an idea of all sponsors, the purpose of each sponsor's funding, and the amount donated, the following information requirement for the firefighter station's database is proposed as: (8IR): *"List of all donations for member competitions in 2023".* Additionally, this information requirement confirms the sponsor's desire to promote and improve firefighting and encourages further cooperation.

A large part of sponsorship donations, except for the costs of the youth and senior competitions, is also tied to firefighting equipment and intervention equipment, so the next information requirement has been identified as follows: (9IR): *"Which personal equipment was donated by the sponsor 420AD in 2023?".*

After identifying all necessary informational requirements for the firefighter station an analysis of all the data needed in the database was made in order to achieve the defined informational requirements. Therefore, data analysis of defined information requirements resulted in 17 objects needing further modelling to accomplish stated information requirements.

The conceptual modelling phase began by identifying 17 entities along with their attributes. In the next step, interactions between identified entities are discussed. Based on the identified relationships between the entities, the Entity-Relationship Model has been developed. Accordingly, by defining the entities, their characteristics, and their relationships, the conceptual model phase was completed.

According to the Entity-Relationship model shown at Figure 1, the relational model identified a total of 20 relations, with three new relations emerging from the M:M relationships between the following entities: i) BOARD and FUNCTION (BOARD_FUNCTION), ii) SOURCE_FUNDING and CONTEST (FUNDING), and iii) CONTEST and MEMBER (PARTICIPATION). Defined entities within the conceptual model and established relations within the relational model are shown in Table 1.

Table 1
Entities from the conceptual model VS relations from the relational model

No	Entity name	Relation name	Conc_M	Relat_M
#1	member	MEMBER	√	√
#2	type_membership	MEMBERSHIP_TYPE	√	√
#3	membership_card	MEMBERSHIP CARD	√	√
#4	status_membership	MEMBERSHIP_STATUS	√	√
#5	unit	UNIT	√	√
#6	medical_examination	MEDICAL_EXAMINATION	√	√
#7	intervention	INTERVENTION	√	√
#8	Intervention_role	INTERVENTION_ROLE	∅	√
#9	type_intervention	TYPE_INTERVENTION	√	√
#10	board	BOARD	√	√
#11		BOARD_FUNCTION	∅	√
#12	function	FUNCTION	√	√
#13	leader	MANAGER	√	√
#14	source_funding	SOURCE_FUNDING	√	√
#15		FUNDING	∅	√
#16	contest	CONTEST	√	√
#17	contest_type	CONTEST_TYPE	√	√
#18		PARTICIPATION	∅	√
#19	firefighting_equipment	FIREFIGHTING_EQUIPMENT	√	√
#20	city	CITY	√	√

Source: Authors work (2024)

Figure 1
Entity-Relationship Model
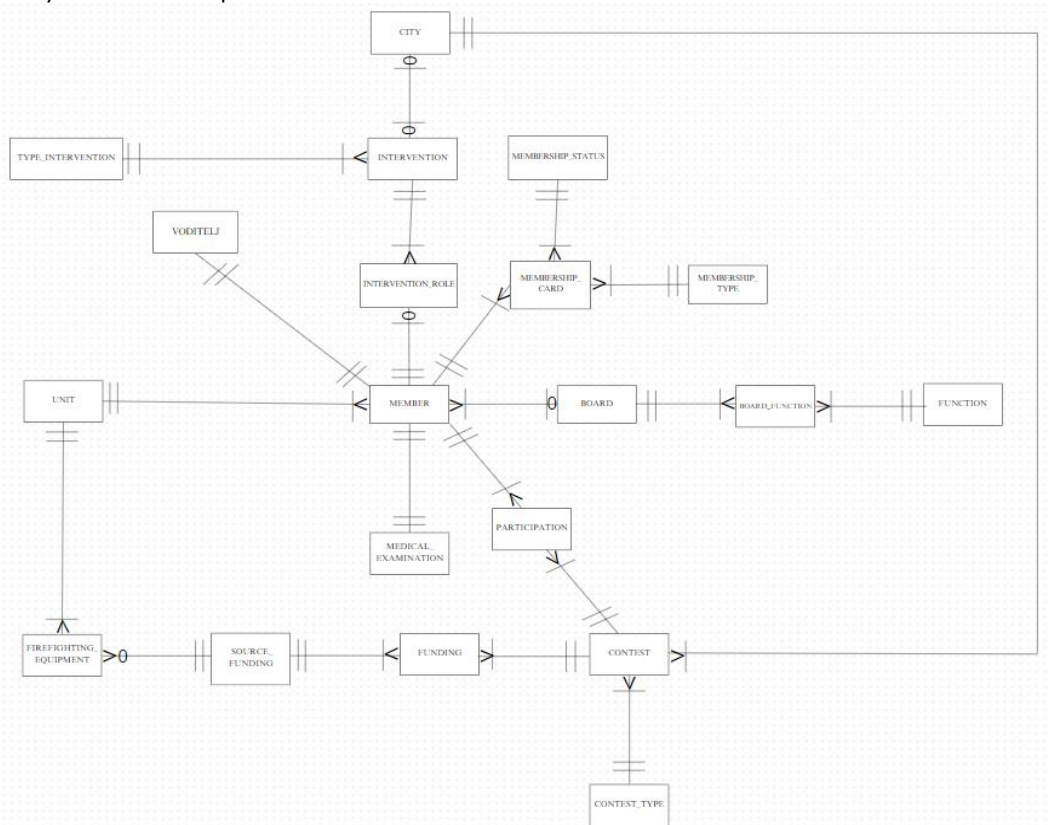
Source: Authors work (2024)

Discussion

Based on the relational scheme, a database was made from which all the information requirements were made using SELECT statements.

From the initial inquiry results, it can be inferred that new members are registered in the youth and young adults' category. Therefore, the society managed to enrol and attract new child members. Enrolment of children is crucial for society to prepare for the upcoming "generation change." Therefore, attention and importance are added to the young firefighters who work with children and younger people.

For the firefighter station to be capable of intervention and to have a permit to work and go out for interventions, it must have at least ten operational adult firefighters who have a valid medical examination performed every two years. From the results of the second information request, it can be concluded that the firefighter station is ready for all operational activities, as it has as many as fourteen members with valid operational criteria. Likewise, this was confirmed by the third information request, which showed a relevant list of all operational members of the firefighter station who had their medical examinations a year earlier or later.

According to the results of the fourth information requirement, it can be concluded that the firefighter station invests in the personal equipment of its firefighters, thus taking care of their safety at every moment of intervention or when performing other operational and technical tasks.

The fifth information requirement's result shows in more detail the functions found within the board of directors, the firefighter station's supervisory board, and other boards. The board of directors is the most important because it makes important decisions for the entire work of the firefighter station, and these include the secretary, recorder, and president of the board of directors, who, in the case of observing the firefighter station, is also the president of the firefighter station.

Interaction, participation, and work with children and young people are important factors of influence by which younger members would become interested in firefighting, acquire a new skill, and take the leadership position of training younger ages themselves. The result of the sixth information request provides a list of members who hold the position of leader and have a desire to invest knowledge and free time in the younger members of the firefighter station.

When it comes to competitions, many children participate based on their abilities and other commitments. However, a large number of children are regulars at training and competitions, so the result of the seventh information requirement helps managers reward the most active junior firefighter competitors after the competition season.

From the eighth information requirement, it can be concluded that the firefighter station participated in almost all-important competitions (county, state, international) and the crown of competitions: The Firefighting Olympiad.

Firefighting equipment is expensive, so any form of donation is welcome in any society or organization. Therefore, the following information requirement is intended to demonstrate the purpose of the selflessly donated equipment by a generous sponsor. This is particularly important since at the end of each year and the regular annual meeting, the firefighter station likes to thank its sponsors with commemorative plaques and thank-you notes, so this kind of inquiry is of great importance and help.

The result of the last information requirement shows the connection between sponsor funding and the competition. Some competitions, such as national, international, and regional, require their financial expenses. Therefore, financial and material donations are greatly helpful in organizing and participating in

competitions. Based on the results of the last information requirement, it can be concluded that nearly every major competition, whether national or organized by the Croatian Fire Association, had at least one sponsor providing financial or material support.

Conclusion

The topic of the paper is to show how database modelling effectively affects the operations of a specific firefighter station. The firefighter station's database was modelled using conceptual and relational models to meet the initial information requirements of its users, specifically the firefighter station members. Valuable data about the firefighter station and its operations were obtained through information requirements, serving as a case study methodology for this paper. The information requirements for the firefighter station were addressed using the SQL programming language. It involved creating tables and attributes based on the established conceptual and relational models. The tables have been filled with data using the MS Access programming tool for database management. From the results of the information requirements, it can be concluded that the firefighter station faces the problem of financing the firefighter station. Also, the obtained results revealed the lack of interested adult members in volunteer firefighting, as well as the lack of the youngest members who express a desire to socialize, play, and learn about firefighting through exercises with firefighting equipment. The created database model greatly supports the monitoring and movement of the firefighter station's operations, and it also facilitates their work with data, provides visual transparency to the data, and makes the firefighter station innovative and modern. Therefore, the created database model makes a great contribution to the firefighter station because it facilitates the daily activities and work of the society. The visualization, simplicity of the data, and transparency of the database, as well as the innovative advantage, will greatly portray the firefighter station as an ambitious and responsible society that invests in technological innovation to improve its operations.

The limitations of this work are that it is necessary to talk with members from other firefighter stations to identify more information requirements that they need and thus to upgrade the database with new entities, relations, or tables. Therefore, the recommendation for future research is to investigate information requirements in other firefighting stations and to upgrade the database model accordingly.

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