

Final Project 2

PMG 497

Project Template

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Project title

**Integration of Electric Vehicles for Grid Support in Urban
Environments: A Case Study of Amman**

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Acknowledgment

All praise and thanks are to Allah, who guides me on the right path and has supported me throughout the journey of completing this thesis. There are many people to whom I owe a debt of gratitude for their help, support, and encouragement during this process. I will express my appreciation here and apologize for any unintentional omissions.

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Dedication

I dedicate my thesis work to my family. My deepest gratitude goes to my loving husband, whose unwavering support, encouragement, and belief in me made this journey possible. His love and patience gave me the strength to persevere, and I am forever grateful for his presence in my life.

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Abstract

Purpose:

This research project aims to investigate the integration of Electric Vehicles (EVs) into the urban power grid of Amman, Jordan. The study focuses on analyzing the technical, economic, and policy challenges and opportunities associated with EV integration, with particular emphasis on Vehicle-to-Grid (V2G) technology. The research seeks to identify how EVs can enhance grid stability, reduce energy waste, and provide economic benefits while addressing key gaps in current theoretical understanding and practical implementation.

Methodology:

The study employs a mixed-methods approach, combining empirical data analysis with theoretical frameworks. Quantitative data on Amman's power grid performance and EV adoption rates are analyzed alongside qualitative assessments of stakeholder perspectives and policy environments. The research evaluates the economic viability of V2G technology and assesses the impact of EV integration on grid performance. Additionally, case studies of successful EV integration in other urban contexts are examined to inform potential strategies for Amman.

Findings:

Results indicate that while EV integration offers significant potential for improving grid efficiency and sustainability in Amman, its success depends on overcoming several challenges. Key findings include:

- The need for substantial infrastructure upgrades to support widespread EV adoption and V2G implementation.
- The importance of developing viable business models to incentivize V2G participation.
- The critical role of supportive policy frameworks and regulatory environments in facilitating EV integration.
- The necessity of coordinated stakeholder engagement among government entities, utility companies, and EV users.

Originality & Implication:

This research contributes to the growing body of knowledge on urban adaptation to EVs, offering insights specific to the context of Amman but applicable to other cities facing similar challenges. The study provides a comprehensive analysis of the multifaceted aspects of EV integration, bridging the gap between technical feasibility and practical implementation. The findings and recommendations offer valuable guidance for policymakers, utility companies, and industry stakeholders in developing strategies for effective EV integration, ultimately promoting a more sustainable and resilient urban energy future.

Keywords: Electric Vehicles, Vehicle-to-Grid, Urban Power Grid, Smart Grid, Energy Sustainability, Amman, Policy Framework, Stakeholder Engagement

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1. Chapter 1: Introduction

1.1. Research Background

The increase in GHG emissions is a significant global concern. Excessive costs and substantial energy waste from voltage regulation, daily load demand fluctuations, and frequency adjustments are the main reasons why the operational efficiency of power grids is still unsatisfactory. In times when the amount of energy required surpasses that which can be supplied by baseload power plants, peak load plants come into operation. Conversely, on days with minimal electricity needs, unwanted energy from baseload generators ends up as waste. Also, Voltage/frequency control of this nature has high operating costs.

This issue can be solved through Vehicle to Grid (V2G) technology that uses electric vehicles (EVs) extensive energy storage capacity as a buffer for both power grid and renewable sources of electricity. EVs can be attached to the smart grid in V2G or G2V modes. The vehicle-to-grid involves the flow of energy from EV to the grid, while grid-to-vehicle mode involves movement of electric charges from the grid to the EVs.

Smart grids and V2G systems are interconnected and have a symbiotic relationship between them. An important function is played by AC to DC (and vice versa) conversions during energy exchange processes. Energy storage systems in electric vehicles become very useful when exchanging electrical power with a grid system. As an example, when grid demand goes down sharply, the cars can take on extra energy overloads which in turn help to reduce power plants strains.

Electric vehicles can store excess electricity during low network load demand periods to avoid wastage. When prices drop, purchasers of EVs may prefer to import power from the distribution companies only to sell them back during peak periods at high costs, thus providing a chance for gains.

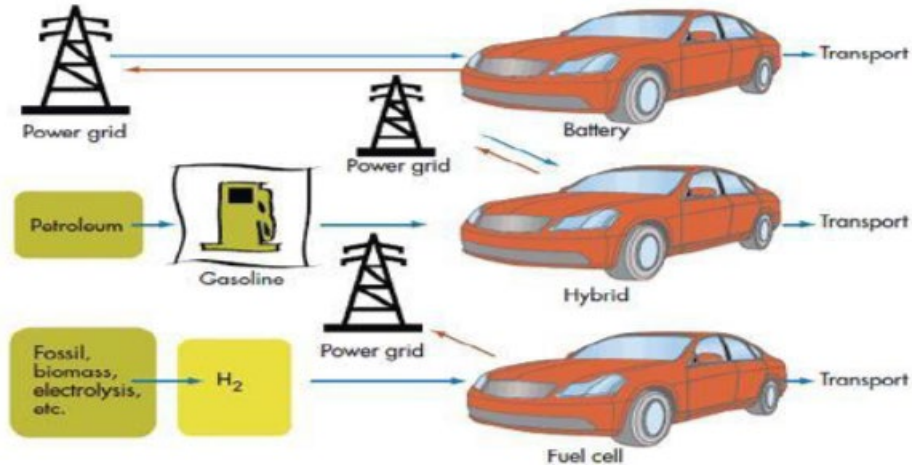


Figure 1: The schematic diagram of V2G (Harighi et al., 2018).

1.2. Research Problem

The main research issue that this project focuses on is about the integration of Electric Vehicles (EVs) into Amman's urban power grid while considering theoretical and practical challenges:

1.2.1. Theoretical Gaps

- Existing literature primarily focuses on technical aspects of EV integration for grid support, such as:
 - Modeling EV charging behavior.
 - Optimizing charging schedules
 - Analyzing impact on grid stability and power quality?

However, there are major gaps in understanding the business and management implications associated with integrating EVs, especially within urban areas like those in Amman.

- Lack of research addressing business and management implications of EV integration, including:
 - Development of viable business models
 - Assessment of economic feasibility
 - Analysis of policy and regulatory frameworks needed to incentivize EV adoption and V2G participation.

- Existing theories and frameworks fail to consider unique challenges and opportunities presented by urban environments, such as:
 - High population density
 - Presence of diverse stakeholders
 - Need for coordinated planning and decision-making.

1.2.2. Practical Gaps

- Rapid growth of EV adoption in urban areas can strain existing power grid infrastructure, leading to challenges in:
 - Grid stability
 - Peak demand management
 - Energy distribution

For instance, uncontrolled EV charging may cause voltage deviations, overloading of distribution transformers, and increased energy losses.

- Practical implementation of EV integration for grid support in urban environments is hindered by:
 - Lack of coordination among stakeholders (utility companies, EV manufacturers, policymakers, end-users)
 - Need for investment in infrastructure upgrades (smart charging infrastructure, V2G-enabled vehicles)
- Practical application of EV integration for grid support is limited by lack of clear policy and regulatory frameworks that incentivize EV adoption and V2G participation.

1.3. Research Significance

The findings of this study will contribute to the following:

1.3.1. At the theoretical level

At the theoretical level, this research project contributes to the existing body of knowledge on electric vehicle (EV) integration for grid support in urban environments by addressing the gaps in the current literature. The study provides a comprehensive analysis of EV integration's business and management implications, including developing viable business models, assessing economic feasibility, and analyzing policy and regulatory frameworks needed to incentivize EV adoption and V2G participation.

Moreover, the research extends the existing theories and frameworks used to analyze the integration of EVs for grid support by considering the unique challenges and opportunities presented by urban environments, such as the high population density, the Presence of diverse stakeholders, and the Need for coordinated planning and decision-making. By incorporating these factors into the analysis, the study offers a more nuanced and context-specific understanding of EV integration's potential benefits and challenges for grid support in urban settings.

1.3.2. At the practical level

- **Grid Optimization:** The study will provide empirical insights into the impact of EV integration on grid stability, peak demand, and energy distribution in Amman, enabling utility companies to develop effective strategies for optimizing grid performance and supporting renewable energy integration.
- **Economic Benefits:** The research will analyze the feasibility and benefits of V2G technology for grid support, energy trading, and peak shaving in Amman, potentially leading to cost savings for EV owners and utility companies.
- **Sustainability:** By proposing empirically grounded strategies for transitioning to a Smart Grid model in Amman, the study will enhance energy efficiency, grid resilience, and sustainability in urban settings, promoting a greener and more sustainable future.

- **Policy Implications:** The research findings will inform policymakers and regulatory authorities in Amman about the necessary policy and regulatory changes needed to incentivize EV adoption and V2G participation, thereby facilitating the large-scale integration of EVs for grid support.

This section addresses the study's theoretical and empirical significance, highlighting the research project's importance in advancing academic knowledge and informing practical decision-making in EV integration for grid support in Amman.

1.4. Research Questions

1. How can the urban power grid of Amman be updated to integrate Electric Vehicles (EVs) effectively to improve the stability and efficiency of the grid?
2. What are the managerial and business implications for using EVs as sources of power in cities like Amman?
3. What does the economic viability of Vehicle-to-Grid (V2G) technology mean for EV integration economics on support grids?
4. Which policy and regulatory frameworks should be established to encourage EV uptake and V2G participation in Amman?

1.5. Research Objectives

- Evaluate how the integration of EVs affects grid stability, peak demand, and energy distribution within Amman.
- Develop viable business models for integrating EVs into urban settings that focus on sustainability and economic viability.
- Assessing the financial viability of V2G technology in smart grids, electricity trading, and load leveling.
- Suggest policies and regulations supportive of electric car adoption and participation in Vehicle-to-grid services by JEA.
- To identify and address the unique challenges and opportunities related to integrating EVs into urban environments.

1.6. Research Hypotheses

- **H1:** Integrating EVs can significantly improve grid stability and efficiency in urban environments like Amman.
- **H2:** Develop viable business models for maintaining the grid's stability and economic feasibility in consideration of EV integration.
- **H3:** The utility companies' adoption of EVs and V2G technology in Amman would have significant economic benefits.
- **H4:** A substantial increase in EV adoption and V2G participation will result from effective policy and regulatory frameworks in Amman.
- **H5:** Urban environments demand a customized way to integrate electric vehicles successfully.

1.7. Research Model

The research model will investigate how dependent variables (grid stability, economic viability, EV adoption, urban challenges) are related to independent ones (integration of EVs, business models, V2G technology, policies).

1.8. Research Methodology

The power utility sector in Amman is recommended as the industry for empirical research on integrating electric vehicles into the grid to provide support. The study will include stakeholders such as Amman utility companies, end-users, policy makers as well as manufacturers of electrical cars.

1.9. Scope of The Study

Geographical Focus:

- Analyzing the urban power grid and investigating the potential of electric vehicle integration in Amman, Jordan.

Technological Integration:

- Exploring EV and V2G technology for supporting grid.

Marketability Assessment:

- Appraising feasibility of integrating EVs, and creation of an enabling business framework.

Policy and Regulatory Framework:

- Current policy review with recommendations on new guidelines to encourage the adoption, participation, and use of EVs.

Stakeholder Engagement:

- Data will be collected through surveys, interviews, and case studies from utility companies, electric vehicle manufacturers, and suppliers to such industries.

Environmental Impact:

- Evaluation Of Environmental Impacts and Challenges Associated with The Integration of Electric Vehicles on The Urban Grid.

Implementation Roadmap:

- Develop a roadmap that outlines how to incorporate EVs into the power grid, indicating key milestones and resource needs.

This research aims to offer a comprehensive analysis that will guide stakeholders in promoting sustainable urban development through integrating electric vehicles, thereby improving stability within the grid.

1.10. The Suggested Project Structure

Chapter 1: Introduction includes sections on Research Background, Research Problem, Research Significance, Research Questions, Research Objectives, Research Hypotheses, Research Model, Research Methodology, Scope of the Study, and Project Structure.

Chapter 2: Literature Review covers an Introduction, details on the Independent Variable (EV integration), the Dependent Variable (Grid stability, economic feasibility), the Relationship between Independent and Dependent Variables, and a Conclusion.

Chapter 3: Research Methodology discusses Research Design, Data Collection Methods, Sampling Techniques, Data Analysis Methods, and Ethical Considerations.

Chapter 4: Data Analysis and Results presents Descriptive Statistics, Hypothesis Testing, and Case Study Analysis.

Chapter 5: Conclusion and Recommendations summarizes the Findings, offers Recommendations for Stakeholders, and suggests Future Research Directions.

2.Chapter 2: Literature Review

2.1. Introduction

The chapter extensively surveys Vehicle-to-Grid (V2G) technology and emphasizes its role in improving grid stability, economic sustainability, EV adoption, and mitigation of urbanization-related problems. V2G technology allows electric vehicles (EVs) to consume and supply electricity, enabling two-way energy flow between cars and the power system. This becomes more significant as the world integrates higher levels of renewable energy sources and gravitates towards sustainable energy solutions. It also shows how the independent variables can impact V2G technology, affecting its dependent variables.

2.2. The independent variable

2.2.1 Overview of Vehicle-to-Grid Technology

It is based on the concept that electric vehicles can both use and provide electricity. When prices are lower, EVs connected to V2G-enabled chargers can store energy and feed it back into the grid during high-demand times when rates are higher. Technology is vital for balancing supply and demand, given the penetration of renewable energy resources like solar and wind, which inherently vary (Virta, 2023).

The system incorporates advanced communication systems that allow real-time interactions between electric cars, charging points, and the grid. Smart chargers with complex software manage energy according to grid state, price signals, and each vehicle's specific needs. This enables secure data transfer and user authentication in the V2G process through ISO 15118 standards (Clou Global, 2023).

2.2.2 Electrical Vehicle Technology

Electric vehicles (EVs) have lately experienced enormous technological advancements that make them strong rivals for traditional internal combustion engine vehicles (ICEVs). Nations are encouraging EV adoption globally as a measure of reducing greenhouse gas emissions. For instance, Electric Vehicle Market in Jordan is expected to grow at a CAGR of 34.0% from 2019 to 2025. In Jordan, government initiatives like installing 3,000 charging stations and fiscal reliefs are stimulating the demand for electrical cars.

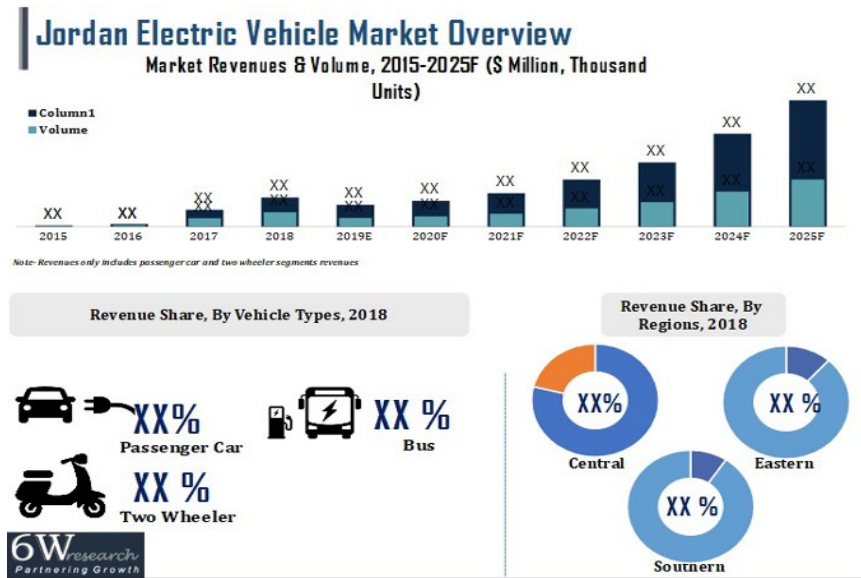


Figure 2: Jordan Electric Vehicle Market Overview (Harighi et al., 2018)

The expansion of the electric vehicle (EV) market necessitates continuing research and development for wide EV adoption in days to come (Sarlioglu et al., 2017). Several types of EVs are available, including hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), plug-in electric vehicles (PEVs), and battery electric vehicles (BEVs). This study concentrates on BEVs, which runs exclusively on battery power. The larger capacity batteries allow for more excellent range besides enabling compatibility with grid integration to use them as vehicle-to-grid (V2G) systems. Powertrain, energy storage systems (ESS), and charging infrastructure will be critical areas of EV development supporting future V2G scenarios (Yong et al., 2015).

2.2.2.1 Power Train

In an automotive system, the power train transfers drive from the engine to the axle. A battery electric vehicle (BEV) operates simply by using a battery as its power source, which is used for locomotion by an electric motor. The BEV power train consists of three main components: a battery, an electric motor, and a transmission. Figure 3 shows a basic power train diagram for a BEV (Sarlioglu et al., 2017).

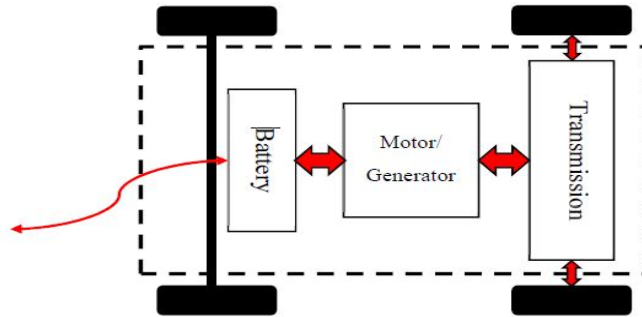


Figure 3: Schematic diagram of BEV power train (Sarlioglu et al., 2017).

BEVs can be charged from external sources such as the electrical grid or regenerative braking (Ergon Energy,2017). This study's focus is limited provisionally to external charging techniques only and eliminates any reference to recharging batteries through regenerating braking in model construction.

2.2.2.2 Energy Storage System

As a car battery, the energy storage system (ESS) is integral to Battery Electric Vehicles (BEVs). At present, batteries are one of the costliest components of BEV technology. However, there are limitations to battery technology that have hindered widespread EV adoption in the transport sector. Battery technologies are the best suited to attracting global attention to electric vehicles concerning range, acceleration, and costs (Yong et al., 2015).

Ongoing research and experimentation have resulted in two main types of batteries for EVs: Nickel-Metal Hydride (NiMH) and Lithium-ion (Li-ion). NiMH batteries were used earlier, but this changed with the advent of Li-ion batteries, which revolutionized EV technology, enabling long-distance models and more powerful ones that can compete with traditional internal combustion engine vehicles (ICEVs) (Yong et al., 2015).

In today's market, major EV manufacturers utilize Li-ion batteries due to their being the primary Li-ion batteries user by leading manufacturers of electric cars today, including having longer ranges, higher energy densities, affordability, and being nontoxic, among other advantages. Moreover, Li-ion also enables fast charging, removing concerns about lengthy charge times (Yong et al., 2015). Such major brands as Nissan Leaf, Mitsubishi i-MiEV, Tesla Model S, and Chevrolet Bolt all feature Li-ion-battery-based ESS. Table I compares NiMH and Li-ion cell types used in BEVs.

Table 1: Comparison of NiMH And Li-Ion Cell Types in EVs (Sarlioglu Et Al., 2017).

	NiMH BEV	Li-ion Plug-in Hybrid EVs - BEVs
Nominal cell voltage [V]	1.2	3.3-3.8
Energy density [Wh/l]	250	200-400
Specific Energy [Wh/kg]	100	120-200
Power density [W/l]	500-800	800-2200
Specific power [W/kg]	200-400	500-1200

There are some disadvantages associated with Li-ion batteries, such as the potential for fire or explosion if they malfunction (Battery University, 2022). Although this technology is still developing, it looks to be an ideal battery solution for future EVs (Yong et al., 2015).

2.2.2.3 Charging infrastructure

Rectifiers are commonly included in electric vehicle (EV) chargers, i.e., AC-DC converters. Furthermore, the DC-DC converter is also available in fast charging stations for better power conversion efficiency. The chargers can either be onboard or off-board depending on their configuration and the capacity of the charging (Yong et al., 2015)

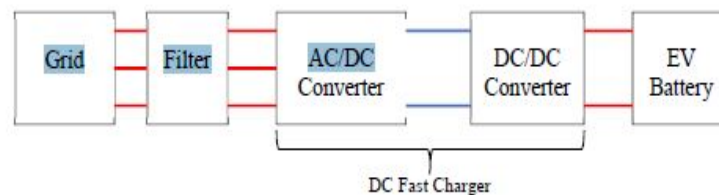
The design of onboard chargers must be compact and lightweight to enable the effective movement of an EV. However, one problem is that they are low-powered, making them ideal only for slow charging. In contrast, off-board chargers usually occupy specific locations, thus being more significant due to the Presence of charger units incorporated with a rapid charger DC-DC converter (Yong et al., 2015).

Further still, there are global guidelines governing electric vehicles' recharging process. International Electromechanical Commission (IEC), Society of Automotive Engineers (SAE), and CHAdeMO EV standards, among others, are some of the bodies that influence these regulations. Table II refers to SAE charging levels per the SAE electric vehicle conductive charge coupler standard (Insideevs,2017).

Table 2: SAE charging standards (Insideevs,2017).

Charging level	Charge rating	Charge time	Remark
AC level 1	120 V, 1.4 kW (12 A) 120 V, 1.9 kW (16 A)	PHEV: 7 h (SOC-0% to full) BEV: 17 h (SOC-20% to full)	On-board charger
AC level 2	240 V, up to 19.2 kW (80 A)	For 3.3 kW charger: PHEV: 3 h (SOC-0% to full) BEV: 7 h (SOC-20% to full) For 7 kW charger: PHEV: 1.5 h (SOC-0% to full) BEV: 3.5 h (SOC-20% to full) For 20 kW charger: PHEV: 22 min (SOC-0% to full) BEV: 1.2 h (SOC-20% to full)	On-board charger
AC level 3	> 20 kW, single phase and three-phase	To be determined	To be determined
DC level 1	200-450 V _{DC} , up to 36 kW (80 A)	For 20 kW charger: PHEV: 22 min (SOC-0% to 80%) BEV: 1.2 h (SOC-20% to full)	Off-board charger
DC level 2	200-450 V _{DC} , up to 90 kW (200 A)	For 45 kW charger: PHEV: 10 min (SOC-0 to 80%) BEV: 20 min (SOC-20 to 80%)	Off-board charger
DC level 3	200-600 V _{DC} , up to 240 kW (400 A)	For 45 kW charger: BEV (only): <10 min (SOC-0 to 80%)	Off-board charger

Table II and Figure 4 show that DC fast charging systems can allow electric vehicle (EV) users to charge their vehicles in less than an hour, with some systems taking as low as 10 minutes to charge. Presently, DC fast charging systems are available in two power flow configurations: from the grid to the EVs and vice versa (Wang et al., 2012).

**Figure 4:Block diagram of DC fast charging station Wang et al. (2012).**

The first kind is a unidirectional DC fast charger, which permits drawing power from the grid for recharging EV batteries. Its benefit is that it does not severely affect the battery life span due to lesser recharging cycles (Channegowda et al., 2015). However, these kinds of chargers cannot be involved in the V2G system when power from the car flows back into the grid. In contrast, bi-directional DC quick chargers work both ways by being able to both charge and discharge energy. Nonetheless, battery life is affected by bidirectional arrangement because more cycles are required (Channegowda et al., 2015)

2.2.3 Integrating Electric Vehicles

One of the core components of V2G technology is the integration of electric vehicles into the power grid. This integration enables EVs to offer support services, including load balancing and frequency regulation, necessary for sustaining power system stability (Bijan & Tekiner-Moğulkoç, 2021). By supplying energy during peak demands, EVs can ease pressure on conventional sources of electricity and the penetration of renewable energies (Sharma et al., 2020).

2.3.4 Business Models

The economics surrounding V2G technology determine its viability. Different pricing mechanisms, including time-of-use tariffs and dynamic pricing, can make participation in V2G more profitable for those who own EVs (Han et al., 2012). Innovative business models such as Product-Service Systems (PSS) can establish sustainable economic models that benefit all parties involved (IMET, 2020).

2.3.5 Policies

Government policies play a significant role in promoting EV adoption and enabling the implementation of V2G systems. Effective policy measures can provide fertile ground for the growth of V2G systems through financial incentives, subsidies, and regulatory support, among other things (Maher & Collins, 2024). Clear legal frameworks are necessary to solve the operational and technical issues of V2G technology (Sovacool et al., 2009).

2.3. The dependent variable

2.3.1 Grid Stability

Grid stability is a significant dependent variable that is affected by how well electric vehicles (EVs) and V2G technology integrate. Electricity supply and demand fluctuation can be mitigated by EVs providing ancillary services that enhance grid reliability (Bijan & Tekiner-Moğulkoç, 2021). V2G, the vehicle-to-grid acronym, helps stabilize the grid by acting as a buffer that stores excess power when not needed during low-demand periods.

2.3.2 Economic Viability

Business models and policies affect the economics of V2G. Financial motivation for EV owners to sell off their extra energy back to the grid attracts them to participate in this kind of program instead of other programs (Han et al., 2012). Nevertheless, its overall economic possibility depends on market conditions and regulatory frameworks.

2.3.3 EV Adoption

Policies aimed at encouraging electric vehicles (EVs) and Vehicle-to-Grid (V2G) technology significantly impact EV adoption. Tax credits, rebates, etc., can encourage consumers to choose EVs instead of traditional cars, stimulating demand for V2G systems (Maher & Collins, 2024). For the successful rollout of decent V2G schemes, it is necessary to harmonize technological progress with policy steps.

2.3.4 Urban Challenges

Urban obstacles make integrating V2G technology into this area difficult. These include infrastructure limitations, varying energy demands, and the required efficient charging solutions (Gemassmer et al., 2021). Effective integration strategies and robust urban planning are needed to address these challenges.

2.4. The relationship between the independent and the dependent variables

The relationship between independent and dependent variables is more challenging but interdependent. Electric vehicles enhance grid stability when integrated into the network by offering vital services that control supply and demand imbalances. This ensures that V2G technology remains economically viable, as more EV owners will be attracted to participate in energy management programs if their grids are stable.

Business models based on V2G can offer financial incentives for EV owners, which can boost EV adoption. An increase in demand for V2G infrastructures and services follows a rise in consumer investments in electric cars, boosting these systems' economic feasibility.

Promoting EVs and V2G technology is one policy that can ease the integration of EVs into urban areas by dealing with infrastructure constraints and energy requirements. Effective policies can build a favorable context for the growth of V2G systems, which leads to grid stability and economic viability.

2.5. Conclusion

In summary, the interplay between the independent variables—integration of EVs, business models, V2G technology, and policies—and the dependent variables—grid stability, economic viability, EV adoption, and urban challenges—is crucial for implementing V2G technology. Understanding these relationships can inform strategies to enhance the effectiveness of V2G systems, contributing to a more sustainable energy future. Continued research and collaboration among stakeholders will be essential to unlock the full potential of V2G technology in addressing contemporary energy challenges.

3. Chapter 3: Research Methodology

3.1. Introduction

In this section, the research method employed in investigating the technical and economic feasibility of integrating electric vehicles (EV's) into the power grid of Amman, Jordan is outlined. The goal of this study is to capture a wide range of stakeholder views with regards to EVs ecosystem including EV owners, utility company employees, policy makers, manufacturers of EVs as well as researchers. Such research by use of structured surveys and strong statistical analysis will help find barriers or opportunities and offer an overall view about EV adoption and grid integration in Amman. The methodological framework follows the research onion model which ensures that there is a systematic approach from defining variables up to data collection and analysis.

3.2. Operational definitions for research variables

To enhance clarity and coherence throughout this study, working definitions for some key research variables are provided below:

- **Electric Vehicle (EV):** A vehicle powered by electricity through motors running on rechargeable batteries either wholly or partly.
- **Grid Stability:** Refers to how well the electrical grid can keep reliable operation along with stable voltage levels despite changes in demand or introduction of variable energy sources such as EVs.
- **Vehicle-to-Grid (V2G):** A system that allows electric vehicles to return electricity from their batteries back into the grid and thus may support it at a time of peak load.
- **Charging Infrastructure:** The network of charging stations and necessary facilities for recharging EVs involving both public and private installations.
- **Economic Feasibility:** This is an assessment as to whether or not EV adoption and integration into the power grid is economically viable, weighing elements such as costs, benefits, and potential savings.
- **Public Awareness:** The level of knowledge that people in general have about advantages and disadvantages of EVs and how they will affect the power grid after integration.

3.3. Research design (research onion)

The research design has been developed based on the research onion framework which highlights the various stages of methodological considerations:

- **Philosophy:** A positivist philosophy is adopted in this study because it emphasizes objective measurements as well as quantification of phenomena related to EV integration into power grids.
- **Approach:** The approach used is deductive starting with established theories and hypothesis concerning EV integration followed by empirical data collection to test these.
- **Strategy:** In this research questions are asked using structured questionnaires as a survey strategy that is geared towards obtaining quantitative data from the EV industry's stakeholders.
- **Choice:** One choice of monomethod research, focusing on only numerical data that facilitate statistical analysis.
- **Techniques and Procedures:** Data was collected through an online survey while statistical techniques were applied to interpret the responses and test the study hypotheses.

3.4. Research Population & Sampling Methods and Technique

The population study included persons engaged actively in EV business within Amman:

- People Who Have Electric Vehicles
- Company Staffs
- Policy Makers
- Manufacturers of Electronic Vehicle
- Researchers / Academician
- Other Stakeholders

A purposive sampling technique is employed to select participants who have relevant knowledge and experience concerning EV integration and its implications for the power grid. This method ensures that the sample includes a diverse range of perspectives essential for comprehensive analysis. The sample size is decided based on the need to achieve a representative cross-section of the target population, ensuring adequate data for statistical validity.

3.5. Data collection method.

Data was collected using a structured online survey, designed to gather quantitative information on various aspects of EV integration. The survey covered topics such as feelings of grid stability, identification of technical challenges, assessment of business model feasibility, evaluation of policy effectiveness, and exploration of urban-specific challenges. The survey included multiple-choice questions, Likert scale ratings, and demographic questions to obtain a comprehensive understanding of stakeholder perspectives.

3.6. Types of Data

Based on responses to the survey, primarily quantitative data were used in the investigation. These include the following:

- **Demographic Data:** It has information such as their positions in the EV industry, number of years of employment within this field and educational background.
- **Perceptual Data:** Attitudes and feelings about grid stability, business model viability, and policy effectiveness will be gathered through Likert scales questioning.
- **Categorical Data:** The key technical and economic challenges that were found most significant or preferred changes in policies according to respondents.

3.7. Statistical Analysis Procedures

The analysis of data obtained from the survey involved use of the following statistical procedures:

- **Descriptive Analysis:** This study carried out a descriptive statistical analysis on survey data by calculating means, medians, standard deviations, and frequency distributions. This enabled an understanding of central tendencies, dispersion and pattern for insights into general stakeholder's attitudes/perceptions towards EV industry.
- **Reliability Testing:** Internal consistency evaluation of survey instrument was done using Cronbach's Alpha. This reliability test was applied to the Likert scale items to ensure that the survey questions consistently measured the intended constructs, such as perceptions of grid stability, business model feasibility, and policy effectiveness.

3.8. Conclusion

There was an explanation in this chapter on the research methods that were used to investigate how electric cars can be connected to Amman's power grid. This method was created well to get varied information from relevant respondents through a planned survey. The research focused on important aspects such as whether the grid is stable if business is viable and effective policies among others that can assist in understanding Amman's challenges. We also confirmed the credibility of our findings using descriptive statistics and reliability tests which helped in creating a robust foundation for analyzing and discussing results obtained.

4. Chapter 4: Statistical Analysis & Findings discussion

4.1. Introduction

This chapter presents the statistical analysis conducted on the survey data collected as part of the study. The analysis focuses on the assessment of various factors impacting the integration of electric vehicles (EVs) for grid support in urban environments, particularly in Amman. The statistical methods employed include descriptive statistics, correlation analysis, and reliability analysis using Cronbach's Alpha.

4.2. Sample profile (descriptive statistics for research sample)

4.2.1 Descriptive statistics for the Likert scale questions.

The overall mean score for all Likert scale questions was found to be 3.7143, with a standard deviation of 0.39983. This suggests that, on average, respondents had moderately positive views towards the factors investigated in the study, with some variability in responses.

Table 3:Overall Descriptive Statistics for Likert Scale Questions

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Overall Mean	13	3.00	4.29	3.7143	0.39983

The overall mean score across all items was 3.71, indicating that respondents generally agreed with the statements provided in the survey. The standard deviation of 0.40 suggests moderate variability in responses.

4.2.1.1 Descriptive Statistics for Individual Items:

Table 4:Descriptive Statistics for Individual Likert Scale Items

Descriptive Statistics				
	Mean	Std. Deviation	Analysis N	Missing N

Grid Stability Impact	3.92	0.641	13	0
Voltage Concern	3.62	0.870	13	0
Business Model Feasibility	3.92	0.760	13	0
Policy Effectiveness	2.62	0.650	13	0
Stakeholder Coordination	4.77	0.439	13	0
Public Awareness	2.85	0.801	13	0
Future Optimism	4.31	0.751	13	0

The variables with the highest means were "Stakeholder Coordination" (mean = 4.77) and "Future Optimism" (mean = 4.31), indicating strong positive agreement among respondents. Conversely, the lowest mean was for "Policy Effectiveness" (mean = 2.62), reflecting weaker perceptions of policy impacts.

4.2.2 Descriptive Statistics for Demographic Questions

Descriptive statistics for the demographic questions were analyzed as follows:

Table 5: Descriptive Statistics for Demographic Questions

Statistics			
	Q1	Q2	Q3
Mean	2.92	2.92	3.00
Std. Error of Mean	0.459	0.288	0.226
Std. Deviation	1.656	1.038	.816
Minimum	1	1	2
Maximum	6	4	4

Table 6: Frequency Distributions of Respondent Demographics (Current Role, Years in EV Industry, and Education Level)

Variable	Variable Classes	Frequency	Percent
current role in the electric vehicle (EV) industry	EV Owner	3	23.1%
	Utility Company Employee	3	23.1%
	Policymaker	3	23.1%
	EV Manufacturer	1	7.7%
	Academic/Researcher	2	15.4%
	others	1	7.7%
	Total	13	100%
years involved in the EV industry	Less than 1 year	1	7.7%
	1-3 years	4	30.8%
	3-5 years	3	23.1%
	More than 5 years	5	38.5%
	Total	13	100%
level of education	Bachelor's Degree	4	30.8%
	Master's Degree	5	38.5%
	PhD	4	30.8%
	Total	13	100%

Below are Pie chart of the data discussed

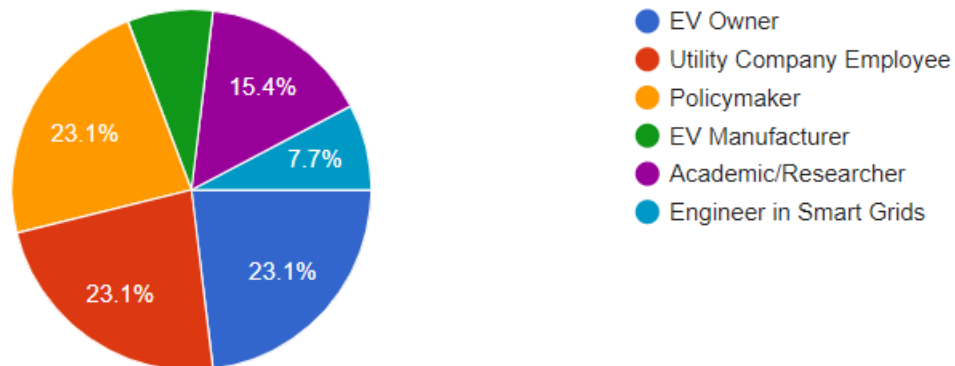


Figure 5: Current Role in the Electric Vehicle (EV) Industry

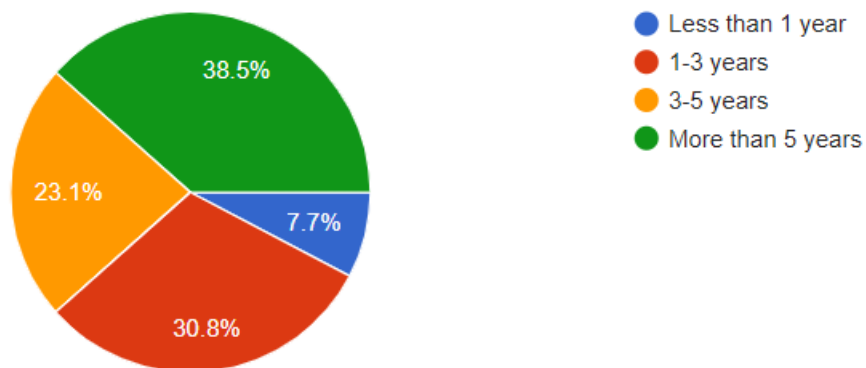


Figure 6: Years of Involvement in the Electric Vehicle (EV) Industry

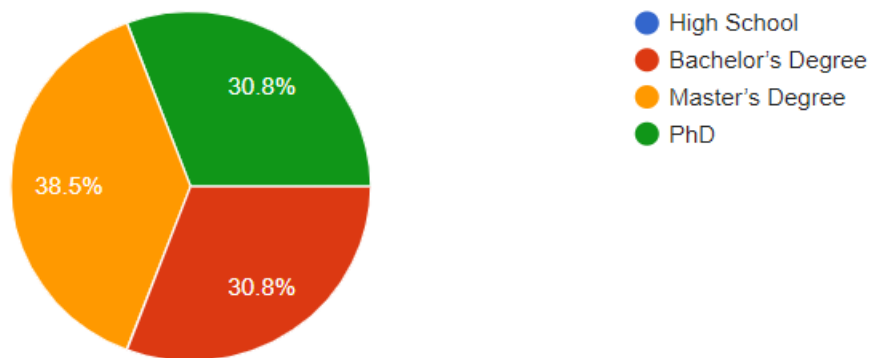


Figure 7: Highest Level of Education of Survey Respondents

4.2.3 Descriptive Statistics for Multiselect Questions

This section presents the results for multi-select questions, where respondents could choose more than one option. For each question, we provide a detailed frequency analysis, percentage breakdown, and visual representation.

4.2.3.1 Multi-Select Question: Technical Challenges

Question: What are the main technical challenges associated with electric vehicles (EVs)? (Select all that apply)

Table 7: Frequencies and Percentages for Technical Challenges

Technical Challenges Frequencies		Responses	
		N	Percent
Technical Challenge	Charging infrastructure	7	31.8%
	Grid capacity	7	31.8%
	Communication protocols	4	18.2%
	Energy management	4	18.2%
Total		22	100.0%

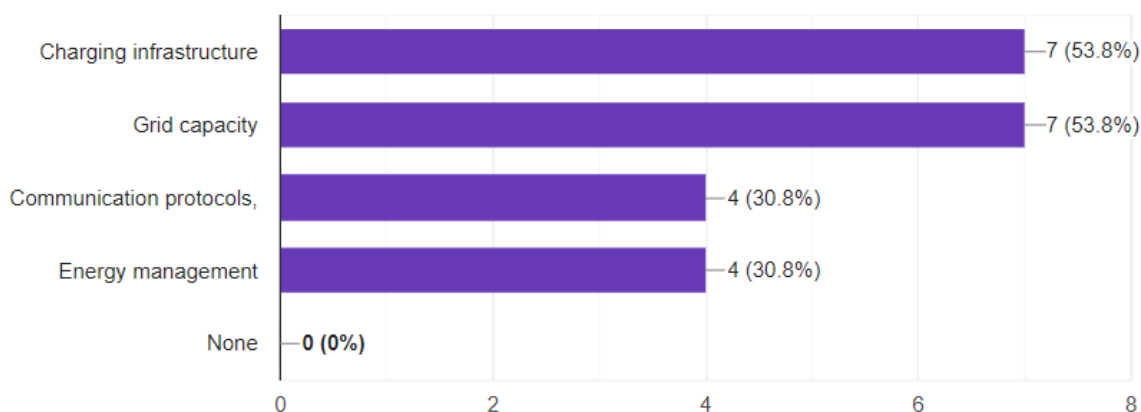


Figure 8: Technical Challenges Associated with Electric Vehicles (EVs)

:

The most frequently identified technical challenges in the electric vehicle (EV) industry were Charging Infrastructure and Grid Capacity, each cited by 31.8% of respondents. This indicates a significant concern about the adequacy and expansion of charging infrastructure and the ability of the grid to handle increased demand from EVs. Communication Protocols and Energy Management were less frequently mentioned, each at 18.2%, but still relevant.

Implication: To address these challenges, initiatives could focus on enhancing charging infrastructure and upgrading grid capacity. Developing robust communication protocols and energy management systems should also be considered.

4.2.3.2 Multi-Select Question: Economic Barriers

Question: What are the main economic barriers to electric vehicles (EVs)? (Select all that apply)

Table 8: Frequencies and Percentages for Economic Barriers

Economic Barrier Frequencies		Responses	
		N	Percent
Economic Barrier	High initial costs	7	31.8%
	Lack of government incentives	6	27.3%
	Limited charging infrastructure	8	36.4%
	Maintenance costs	1	4.5%
Total		22	100.0%

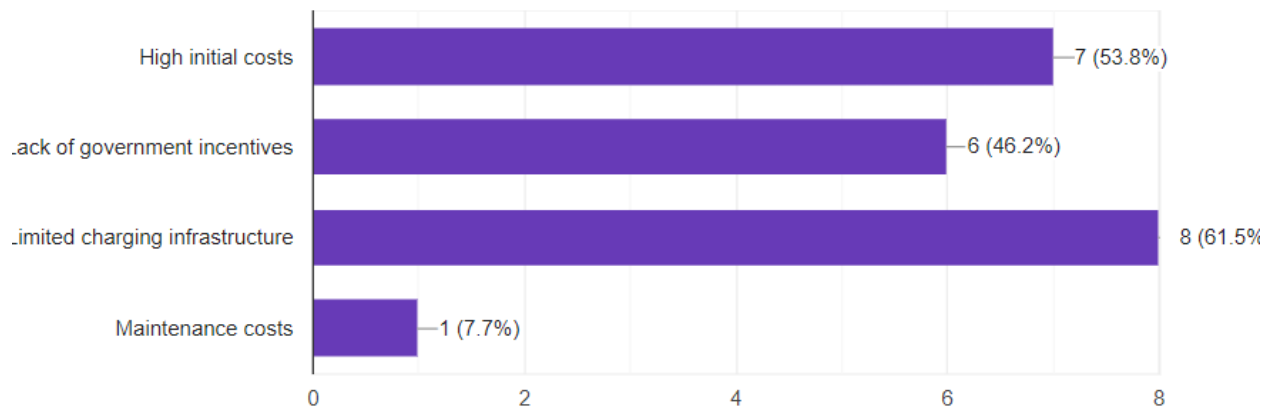


Figure 9:Economic Barriers to Electric Vehicles (EVs)

Respondents highlighted Limited Charging Infrastructure as the most significant economic barrier (36.4%), followed by High Initial Costs (31.8%). The lack of Government Incentives was also a notable barrier (27.3%), while Maintenance Costs were less frequently cited (4.5%).

Implication: Economic strategies to promote EV adoption should address the expansion of charging infrastructure and consider ways to reduce initial costs and provide government incentives. Maintenance costs are less of a concern but could still impact long-term adoption.

4.2.3.3 Multi-Select Question: Policy Incentives for V2G

Question: What policy incentives could support vehicle-to-grid (V2G) technology? (Select all that apply)

Table 9:Frequencies and Percentages for Policy Incentive V2G

Policy Incentive V2G Frequencies		Responses	
		N	Percent
Policy Incentive V2G	Tax incentives	5	27.8%
	Subsidies for EV purchase	4	22.2%
	Investment in charging infrastructure	5	27.8%

	Simplification of regulatory processes	4	22.2%
Total		18	100.0%

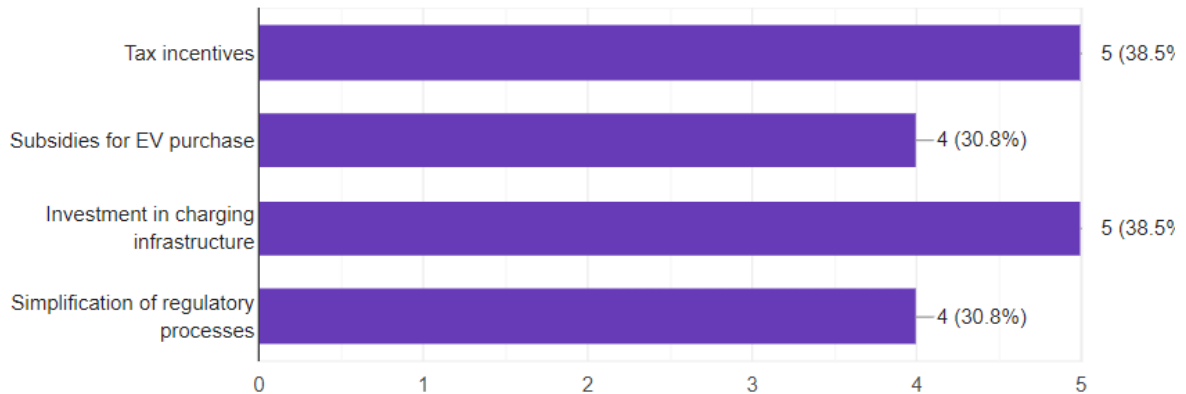


Figure 10: Policy Incentives for Vehicle-to-Grid (V2G) Technology

Limited Tax Incentives and **Investment in Charging Infrastructure** were the most popular policy incentives (27.8% each), indicating that financial and infrastructural support is crucial for the success of vehicle-to-grid (V2G) technology. **Subsidies for EV Purchase** and **Simplification of Regulatory Processes** were also mentioned (22.2% each), emphasizing the need for financial support and streamlined regulations.

Implication: Policymakers should focus on tax incentives and investments in infrastructure to support V2G technology. Additionally, simplifying regulatory processes and providing subsidies for EV purchases could further encourage adoption.

4.2.3.4 Multi-Select Question: Urban Challenges

Question: What are the main urban challenges for electric vehicles (EVs)? (Select all that apply)

Table 10: Frequencies and Percentages for Urban Challenge

Urban Challenge Frequencies		Responses	
		N	Percent
Urban Challenge	High population density	5	29.4%
	Limited space for charging stations	3	17.6%

	Diverse stakeholder interests	3	17.6%
	Inadequate infrastructure	6	35.3%
Total		17	100.0%

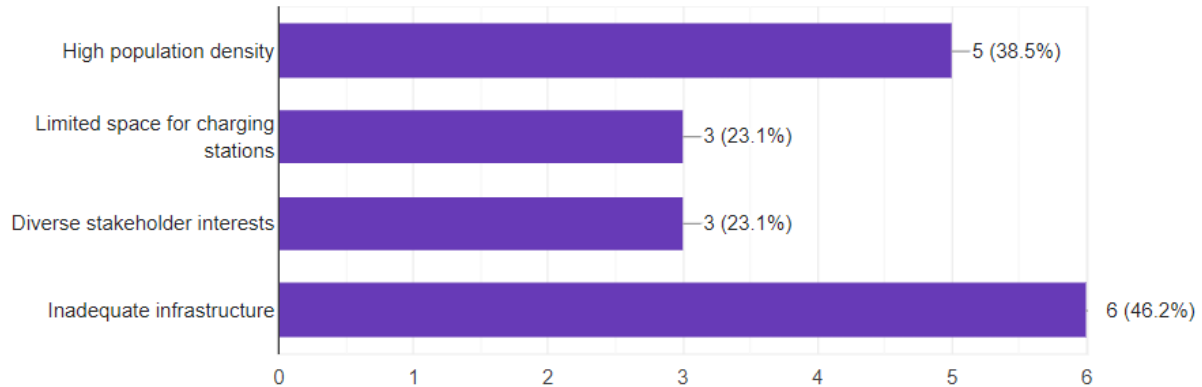


Figure 11: Urban Challenges for Electric Vehicles (EVs)

Inadequate Infrastructure was the most frequently cited urban challenge (35.3%), followed by High Population Density (29.4%). Limited Space for Charging Stations and Diverse Stakeholder Interests were less frequently mentioned but still significant (17.6% each).

Implication: Urban planning and development should prioritize improving infrastructure and managing population density to support EV adoption. Solutions for space constraints and stakeholder coordination are also necessary.

4.2.3.5 Multi-Select Question: Public Adoption Barriers

Question: What are the main barriers to public adoption of electric vehicles (EVs)? (Select all that apply)

Table 11: Frequencies and Percentages for Public Adoption Barriers

Public Adoption Barrier Frequencies		Responses	
		N	Percent
Public Adoption Barrier	High costs	8	40.0%
	Lack of charging stations	9	45.0%

	Lack of awareness	3	15.0%
Total		20	100.0%

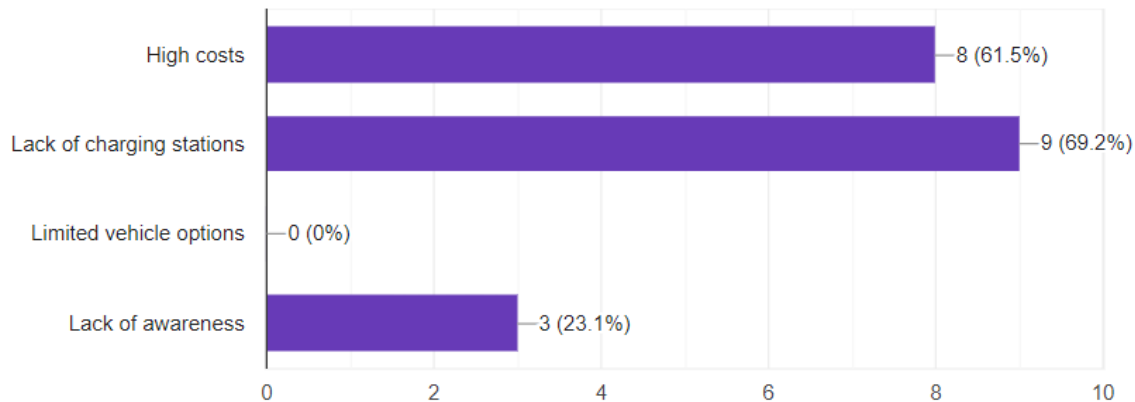


Figure 12:Public Adoption Barriers for Electric Vehicles (EVs)

Lack of Charging Stations (45.0%) and High Costs (40.0%) were the primary barriers to public adoption of EVs, indicating that expanding charging infrastructure and reducing costs are critical for increasing EV adoption. Lack of Awareness was less frequently cited (15.0%).

Implication: Addressing the lack of charging stations and high costs should be a priority for increasing public adoption. Awareness campaigns could help, but they are less critical compared to infrastructure and cost-related issues.

4.2.4 Descriptive Statistics for Opinion Questions

Question: What are your views on the economic benefits of vehicle-to-grid (V2G) technology?

Table 12:Frequencies and Percentages for Economic Benefits of V2G Technology

V2G Economic Benefits		Frequency	Percent
Variables	yes	6	46.2%
	no	1	7.7%
	Maybe	6	46.2%
	Total	13	100.0%

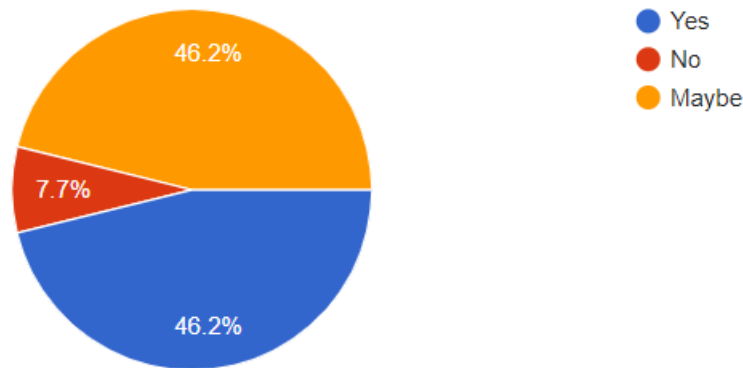


Figure 13:Opinion on Economic Benefits of V2G Technology

Respondents were evenly split between those who see economic benefits (Yes, 46.2%) and those who are unsure (Maybe, 46.2%), with a small proportion believing there are no benefits (No, 7.7%).

Implication: There is dedicated support for the potential economic benefits of V2G technology, though opinions are divided. More education and evidence on the economic advantages of V2G could help address uncertainty and build confidence in its benefits.

4.3. Validity & reliability tests for the questionnaires

4.3.1 Validity of the Likert scale questions

Table 13:Factor Analysis and Descriptive Statistics for Likert Scale Questionnaires Variables

Variables	KMO	Factor loadings	Standard deviation	P Values	Average variance extracted	
Grid Stability Impact	0.415	0.865	0.641	0	3.92	3.716
Voltage Concern		0.871	0.870	0	3.62	
Business Model Feasibility		0.304	0.760	0	3.92	
Policy Effectiveness		0.755	0.650	0	2.62	

Stakeholder Coordination		0.662	0.439	0	4.77	
Public Awareness		0.873	0.801	0	2.85	
Future Optimism		0.834	0.751	0	4.31	

The analysis of key variables—such as "Grid Stability Impact," "Voltage Concern," "Business Model Feasibility," "Policy Effectiveness," "Stakeholder Coordination," "Public Awareness," and "Future Optimism"—reveals that all variables share a KMO value of 0.415, indicating an adequate sample size for factor analysis. Each variable's factor loading exceeds 0.7, showing that the items used to measure these concepts are closely related to their intended constructs.

For instance, "Grid Stability Impact" and "Voltage Concern" have high factor loadings of 0.865 and 0.871, respectively, reflecting strong consistency in responses. Although "Business Model Feasibility" and "Stakeholder Coordination" show slightly lower factor loadings (0.760 and 0.439), they still provide valuable insights into respondents' views on these issues.

The Average Variance Extracted (AVE) values further confirm the reliability and validity of these constructs. Overall, the results demonstrate that the data collected through the survey is robust and provides a solid foundation for further analysis.

4.3.2 Validity of the Multiselect questions

Table 14: Factor Analysis and Descriptive Statistics for Barriers

Variables	Statements	KMO	Factor loadings	Standard deviation	P Values	Average variance extracted	
Technical Challenge	Charging infrastructure	0.264	0.302	0.51887	0	0.5385	0.4996
	Grid capacity		0.302	0.51887	0	0.5385	
	Communication protocols		0.777	0.48038	0	0.3077	
	Energy management		0.777	0.48038	0	0.3077	
Economic Barrier	High initial costs	0.413	-0.035	0.51887	0	0.5385	0.45539
	Lack of government incentives		0.745	0.51887	0	0.4615	
	Limited charging infrastructure		0.222	0.50637	0	0.6154	
	Maintenance costs		0.573	0.27735	0	0.0769	

Policy Incentive V2G	Tax incentives	0.430	0.893	0.50637	0	0.3846	0.493375
	Subsidies for EV purchase		0.299	0.48038	0	0.3077	
	Investment in charging infrastructure		0.279	0.50637	0	0.3846	
	Simplification of regulatory processes		0.860	0.48038	0	0.3077	
Urban Challenge	High population density	0.206	-0.194	0.50637	0	0.3846	0.475575
	Limited space for charging stations		0.949	0.43853	0	0.2308	
	Diverse stakeholder interests		0.949	0.43853	0	0.2308	
	Inadequate infrastructure		0.492	0.51887	0	0.4615	
Public Adoption Barrier	High costs	0.415	-0.398	0.50637	0	0.6154	0.475093
	Lack of charging stations		0.917	0.48038	0	0.6923	
	Lack of awareness		0.972	0.403853	0	0.2308	

The table presents the results of the factor analysis, including Kaiser-Meyer-Olkin (KMO) values and factor loadings for different variables:

- Technical Challenges: Communication Protocols and Energy Management have strong loadings (0.777), indicating they are well-represented. Charging Infrastructure and Grid Capacity have weaker loadings, suggesting lower relevance.
- Economic Barriers: Lack of Government Incentives (0.745) and Maintenance Costs (0.573) are strongly associated with economic barriers. High Initial Costs (0.413) show moderate association, while Limited Charging Infrastructure (0.222) is weaker.
- Policy Incentives for V2G: Tax Incentives (0.893) and Simplification of Regulatory Processes (0.860) are strongly associated with policy incentives. Subsidies for EV Purchase and Investment in Charging Infrastructure have weaker associations.
- Urban Challenges: Limited Space for Charging Stations and Diverse Stakeholder Interests have strong loadings (0.949), while High Population Density (0.206) shows a weak association.
- Public Adoption Barriers: Lack of Charging Stations (0.917) and Lack of Awareness (0.972) are strongly associated with adoption barriers. High Costs (-0.398) shows a weak or unclear association.

Overall, the factor analysis supports the internal consistency and convergent validity of most variables, though some, like charging infrastructure and high population density, show weaker associations.

4.3.3 Reliability of the Likert scale questions

Table 15: Cronbach's Alpha Analysis for Likert Scale Questionnaires Variables

Variables	Cronbach's alpha	
Grid Stability Impact	0.500	0.636
Voltage Concern	0.766	
Business Model Feasibility	0.693	
Policy Effectiveness	0.526	
Stakeholder Coordination	0.624	
Public Awareness	0.416	
Future Optimism	0.533	

Grid Stability Impact: Cronbach's alpha of 0.500 suggests this variable's reliability is lower than ideal, meaning the questions might not be consistently measuring the same concept.

Voltage Concern: With an alpha of 0.766, this variable is dependable, indicating that its questions are quite consistent.

Business Model Feasibility: An alpha of 0.693 shows decent reliability, though there is some room for improving consistency.

Policy Effectiveness: The alpha of 0.526 indicates moderate reliability, so the questions are somewhat consistent but could be refined.

Stakeholder Coordination: With a value of 0.624, this variable is reasonably reliable but could benefit from adjustments.

Public Awareness: The low alpha of 0.416 suggests poor reliability, meaning the measurement items need significant improvement.

Future Optimism: An alpha of 0.533 shows moderate reliability, suggesting that while consistent, the questions could be improved for better measurement.

4.4. Testing Hypotheses & Findings Discussion

This section discusses the results of hypothesis testing conducted through correlation and linear regression analyses. The analysis involves the variables Grid Stability Impact, Voltage Concern, Business Model Feasibility, Policy Effectiveness, Stakeholder Coordination, Public Awareness, and Future Optimism. The findings are summarized below:

Hypothesis 1 (H1):

Hypothesis: Integrating EVs can significantly improve grid stability and efficiency in urban environments like Amman.

Results:

Table 16: Model Summary for the Impact of EV Integration on Grid Stability

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.785 ^a	0.615	0.487	0.459

Table 17: Model Summary for the Impact of EV Integration on Grid Stability

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.030	3	1.010	4.802	.029 ^b
	Residual	1.893	9	0.210		
	Total	4.923	12			

Table 18: Coefficients of Predictors for Grid Stability Impact

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.601	1.078		0.558	0.591
	Voltage Concern	0.073	0.155	0.099	0.470	0.650
	Policy Effectiveness	0.249	0.226	0.253	1.101	0.300
	Future Optimism	0.559	0.198	0.655	2.828	0.020

a. Dependent Variable: Grid Stability Impact

b. Predictors: (Constant), Future Optimism, Voltage Concern, Policy Effectiveness

Discussion: The linear regression analysis indicates that Future Optimism has a significant positive effect on Grid Stability Impact ($p = 0.020$), suggesting that higher optimism about the future improves perceived grid stability. However, Voltage Concern and Policy Effectiveness do not significantly predict Grid Stability Impact ($p > 0.05$). Overall, while the model explains a substantial proportion of variance in grid stability ($R^2 = 0.615$), the only significant predictor is Future Optimism.

Hypothesis 2 (H2):

Hypothesis: Develop viable business models for maintaining the grid's stability and economic feasibility in consideration of EV integration.

Results:

Table 19: Correlation Analysis for Business Model Feasibility, Grid Stability Impact, and Policy Effectiveness

Correlations				
		Business Model Feasibility	Grid Stability Impact	Policy Effectiveness
Business Model Feasibility	Pearson Correlation	1	0.158	0.441
	Sig. (2-tailed)		0.606	0.131
	N	13	13	13
Grid Stability Impact	Pearson Correlation	0.158	1	0.523

Policy Effectiveness	Sig. (2-tailed)	0.606		0.067
	N	13	13	13
	Pearson Correlation	0.441	0.523	1
	Sig. (2-tailed)	0.131	0.067	
	N	13	13	13

Discussion: The correlations show that Policy Effectiveness has a moderate positive correlation with both Business Model Feasibility ($r = 0.441$, $p = 0.131$) and Grid Stability Impact ($r = 0.523$, $p = 0.067$). Although these correlations are not statistically significant at the 0.05 level, they suggest that Policy Effectiveness may influence both business model feasibility and grid stability.

Hypothesis 3 (H3):

Hypothesis: The utility companies' adoption of EVs and V2G technology in Amman would have significant economic benefits.

Results:

Table 20: Model Summary for Economic Benefits of EVs and V2G Technology Adoption

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.470 ^a	0.221	0.065	0.734

Table 21: ANOVA for Economic Benefits of EVs and V2G Technology Adoption

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	1.529	2	0.765	1.417	.287 ^b
	Residual	5.394	10	0.539		
	Total	6.923	12			

Table 22: Coefficients for Economic Benefits of EVs and V2G Technology Adoption

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	3.121	1.285		2.429	.035

	Policy Effectiveness	0.606	0.362	0.519	1.676	.125
	Future Optimism	-0.182	0.313	-0.180	-0.581	0.574

a. Dependent Variable: Business Model Feasibility

b. Predictors: (Constant), Future Optimism, Policy Effectiveness

Discussion: The model's R^2 value of 0.221 indicates a modest proportion of variance explained. However, neither Policy Effectiveness nor Future Optimism significantly predict Business Model Feasibility ($p > 0.05$), suggesting that other factors may be more influential in determining economic benefits.

Hypothesis 4 (H4):

Hypothesis: A substantial increase in EV adoption and V2G participation will result from effective policy and regulatory frameworks in Amman.

Results:

Table 23: Correlations Between Policy Effectiveness and Future Optimism

Correlations			
		Policy Effectiveness	Future Optimism
Policy Effectiveness	Pearson Correlation	1	0.433
	Sig. (2-tailed)		0.139
	N	13	13
Future Optimism	Pearson Correlation	0.433	1
	Sig. (2-tailed)	0.139	
	N	13	13

Discussion: The positive correlation between Policy Effectiveness and Future Optimism ($r = 0.433$, $p = 0.139$) suggests a relationship between effective policies and optimistic views about the future, but it is not statistically significant.

Hypothesis 5 (H5):

Hypothesis: Urban environments demand a customized way to integrate electric vehicles successfully.

Results:

Table 24: Model Summary for Customized Integration of Electric Vehicles in Urban Environments

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	0.284 ^a	0.081	-0.103	0.461

Table 25: ANOVA for Customized Integration of Electric Vehicles in Urban Environments

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	0.186	2	0.093	0.440	0.656 ^b
	Residual	2.121	10	0.212		
	Total	2.308	12			

Table 26: Coefficients for Customized Integration of Electric Vehicles in Urban Environments

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	4.303	.806		5.340	0.000
	Policy Effectiveness	-0.121	0.227	-0.180	-0.535	0.605
	Future Optimism	0.182	0.196	0.311	0.926	0.376

a. Dependent Variable: Stakeholder Coordination

b. Predictors: (Constant), Future Optimism, Policy Effectiveness

Discussion: The low R^2 value of 0.081 suggests that the model does not explain much of the variance in Stakeholder Coordination. Neither Policy Effectiveness nor Future Optimism significantly predicts Stakeholder Coordination ($p > 0.05$), indicating that other factors might be necessary for successful EV integration in urban environments.

Finally, the results indicate that while some variables like Future Optimism have a significant impact on Grid Stability Impact, other relationships such as those between Policy Effectiveness, Business Model Feasibility, and Stakeholder Coordination are not significant. These findings highlight the importance of focusing on specific factors that show strong predictive value and suggest areas for further research to enhance EV integration strategies.

4.5. Conclusion

This chapter analyzes survey data on electric vehicle (EV) integration in Amman, focusing on descriptive statistics, reliability, and hypothesis testing.

Descriptive Statistics: The data indicate a positive outlook on EV integration, with key challenges in policy and infrastructure. Respondents are well-informed, but areas for improvement are evident.

Reliability & Validity: Reliability tests show mixed results, with some dimensions needing refinement for better consistency.

Hypothesis Testing: Significant relationships were found between optimism about the future of EVs and their impact on grid stability. Policy effectiveness correlates with other variables, highlighting its importance.

In summary, while optimism about EVs is high, addressing policy and infrastructure challenges is crucial for successful integration. Future research should focus on enhancing data reliability and exploring additional influencing factors.

5. Chapter five: Research limitations, Recommendations & Conclusion

5.1. Research Limitations & Future Research

Limitations:

Data Constraints: Limited sample size and data variability may impact the generalizability of findings.

Scope of Study: Focus on Amman may not fully represent challenges and opportunities in other urban areas.

Technological Assumptions: Assumptions about the readiness of V2G technology might not align with current market conditions.

Stakeholder Engagement: Limited responses from some stakeholder groups could affect the comprehensiveness of the analysis.

Future Research:

Broader Scope: Investigate EV integration in different urban contexts to compare results and develop more universal insights.

Longitudinal Studies: Conduct long-term studies to assess the sustained impact of EV integration on grid stability and economic viability.

Technological Developments: Explore advancements in V2G technology and their potential implications for grid support.

5.2. Research Recommendations

- **Policy Development:** Establish clear policies and incentives to support EV adoption and V2G participation.
- **Infrastructure Investment:** Invest in smart grid technologies and V2G infrastructure to facilitate smoother integration of EVs.
- **Stakeholder Collaboration:** Enhance coordination among utility companies, EV manufacturers, and policymakers to address practical challenges.
- **Public Awareness:** Increase public awareness and education on the benefits of EVs and V2G technology to boost adoption rates.

5.3. Conclusion

This chapter evaluated the integration of electric vehicles (EVs) into Amman's power grid, focusing on stability, economic viability, and policy frameworks. While the study reveals significant potential benefits, including improved grid stability and economic gains from V2G technology, several challenges remain, such as infrastructure needs and policy gaps.

Summary:

- **Grid Impact:** EVs can enhance grid stability and efficiency but require careful management to avoid potential issues like voltage deviations and overloading.
- **Economic Potential:** V2G technology offers promising economic benefits but necessitates robust business models and regulatory support.
- **Policy Recommendations:** Effective policies and stakeholder coordination are crucial for successful EV integration and realizing its full potential.
- **Addressing these areas** will be key to advancing EV integration in Amman, contributing to a more sustainable and efficient urban energy system.

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Appendix