VALUE-BASED CONNECTED AUTONOMOUS VEHICLES BUSINESS MODELING

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Abstract

Connected Autonomous Vehicles (CAV) industry is expected to grow rapidly in the upcoming years. Many enterprises will need to adapt new techniques to be able to participate in CAV growth. Although some manufacturers promise high level of automation by 2025, the needed infrastructure investment will take longer time due to the huge investments' capital and the time needed for constructions. CAV will need to continuously communicate with their surroundings in order to guarantee efficient and safe trips. One of the main communicating methods is Vehicle to Infrastructure, which mainly depends on Roadside Equipment in North America.

There's a need to give decision makers best possible information to help them make investment decisions and define risks. Profit and Loss analysis is not enough because it doesn't cover operational design, value creation, or value exchange in the business ecosystem. A sound knowledge of business operations through business modeling will allow business owners to take proper investment decisions and perform proper risk identification and consequently, choose the appropriate risk management strategies.

Traditional business modeling techniques are insufficient to cope with elements of CAV and investment decisions. Supply Chain Operating Reference (SCOR), Value Network Analysis (VNA), Value Reference Model (VRM), and e3Value were all specific business modeling techniques which targeted supply chain or economic values. The Value Management Modeling Language (VDML) is a superior approach because it addressed value creation and value exchange in the ecosystem and provided deep understanding of business operations. Road owners need VDML business modeling to study the possibility of making their roads ready for Connected Autonomous Vehicles (CAV) operations. No previous modeling attempts were made for this purpose. Also, to reduce service development risks, business owners will need to guarantee alignment and reduce service development time and cost.

In this research a methodology has been suggested to use the VDML based Value Management Platform (VMP) to assist the road owners in their decision and allow them to perform risk identification and take investment decisions. The model was validated against previous years' financial data of 407ETR as an example of a road owner and was projected to four years of operations. Using the Unified Modeling Language (UML) for service development achieves intracompany alignment which reduces service development risks. The VMP tool did not produce UML use case diagrams, therefore, a tool has been developed to supply VMP-based UML use case diagrams.

Keywords: *CAV, VDML, VMP, RSE, DSRC, UML, Road Owner, Decision-Making, Risk Identification.*

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Chapter 1

1.1 Motivation

One of the main areas of Smart City initiatives is transportation. The (Intelligent Transportation System) ITS is a mandatory initiative to reach a fully automated transportation smart network where the traffic conditions road conditions, and weather conditions are all integrated and processed to achieve safer and more efficient transportation through the city. (Connected Autonomous Vehicles) CAV manufacturers promise a high level of automation by 2025. Other studies have anticipated that CAV will be available by 2040 or 2060. The estimated market size of CAV worldwide is forecasted to be $77B by 2035 [13]. This new business will disrupt existing industries, yet, it will create more jobs in new fields, especially in the context of the smart cities. Consequently, deep understanding of the business ecosystem is required to be able to anticipate the risks and define the proper risk management strategies. Also, such an understanding is imperative for business owners to have enough knowledge that will help them decide on future investments.

In Apr 2018, the World Economic Forum article [2], drew attention to the fact that Autonomous Vehicles will need a lot of infrastructure investments to become fully operational. The author suggested a framework for CAV to be integrated with the infrastructure, where three main streams were needed: Asset Management, Licensing, and Standards. CAV should be able to observe the road data through many inputs and analyze the data to decide on the action needed, then take that action. Moreover, standards and legislation need to be set for CAV at every level of the six levels of automation. Asset management of the infrastructure should be designed based on the standards. The article predicted CAV to go commercial by 2025, however, the transportation systems, due to a need for constructions and roll out of RSE or 5G upgrades, will not be ready for it before 2070. "As we rapidly approach the point at which CAV are ready for our streets, we have to make sure that our streets are ready for them" [2]. Only 5G networks will support CAV operations, and the difference between 4G and 5G networks is discussed by Dean [3].

The CAV will need to communicate to other vehicles, Road Side Equipment (RSE), and 5G mobile telecommunication networks. The reason for that needed communication is that CAV will need to process data from other vehicles, RSE, and other sources of data, such as traffic control centers, in order for the CAV to have full knowledge of road conditions, weather conditions, and other vehicles' data, which in turn will help the CAV take operating decisions to provide safe trips. The CAV ecosystem requires many communication technologies to operate and cover the Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Vehicle to Pedestrian (V2P), Pedestrian to Vehicle (P2V), and, on a broader concept, Vehicle to Everything (V2X). Huge investments and large time frames are needed to execute the needed 5G rollout projects. Also, RSE deployment is a huge challenge. In [4], the authors pointed out that The Dedicated Short-Range Communication (DSRC) will offer 7 channels to insure the safety on the road along with other applications, low latency, and high data transfer rates of 6 to 27 Mbps. However, the DSRC base stations will need to be constructed not more than 1000m apart, which, like 5G networks, reflect a huge investment and long deployment times.

Moreover, CAV use Cameras, sensors, Light Detection and Ranging (LiDAR), and Global Positioning System (GPS) to be in constant communication with all surroundings. The LiDAR system emits infrared beams to the surrounding environment, and it allows the

CAV to recognize all moving and non-moving objects around it. The LiDAR allows the vehicle to decide if a surrounding object is a threat and consequently avoid collisions.

As the challenges mount for policymakers and investors in each country, the readiness level for the world's countries is not the same. As advanced steps were taken by Netherlands, Singapore, and USA, other countries are still moving in the direction of upgrading their technology infrastructure. The UK has already announced that it will be ready for CAVs by 2020. For Canada, Ontario Regulation 306/15 [5] took effect on Dec 2017 and is aimed at the legislation of testing the CAVs over 10 years.

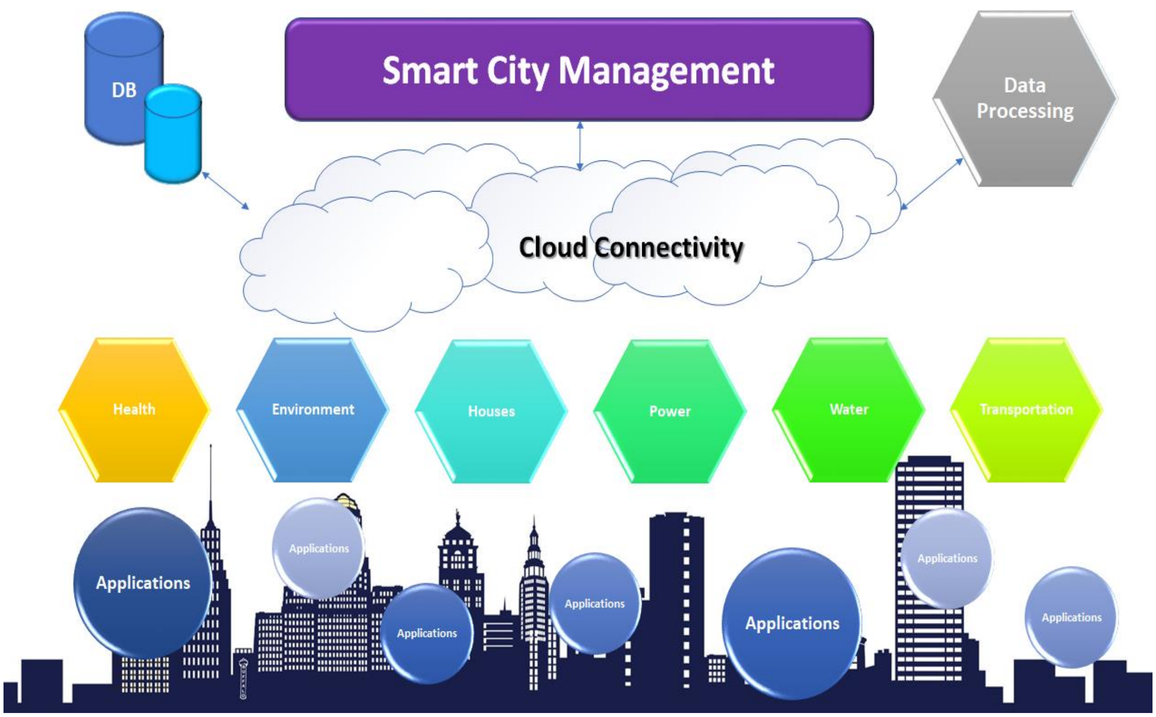


Figure 1 Transportation as part of a smart city

Figure 1 shows the Smart City framework where smart services integrate to form the smart city ecosystem. "More than half of the World's population now lives in urban areas" [1] and this increases the importance of smart city applications. People and businesses are using a lot of applications in many fields that add value to their daily lives. Public health is one of the main pillars where value can be added to every citizen. Many initiatives were applied such as wearables that can transfer all vital signs of patients to their treatment centers remotely, which is a very efficient way to save lives and to reduce hospital admission. Environmental monitoring is also another important area where wireless sensor networks can be deployed to avail continuous monitoring of environmental conditions, consequently, better managements of resources is achieved, and swift actions are taken. A monitored and controlled power grid will make it easier to manage and more efficient; and having remote sensors that can measure the water levels, composition, and distribution makes it a lot more feasible to maintain clean and sustainable water supplies. Transportation is the field where optimization can lead to huge economic benefits. Initiatives were always considered to facilitate the transportation whether it is single or multimodal. ITS infrastructure is widely used in many cities around the world.

1.2 Problem Definition

Business owners and decision makers are required to take sound business decisions. There are many variations of the decision-making process that can be found in Anwar Ahmed article [57]. All the decision-making processes can be summarized as *“(1) perception of the problem or opportunity, (2) formulation of alternatives, (3) evaluation of alternatives and (4) choosing one or more alternatives for implementation*” [56]. To support formal decision-making, sound knowledge of the business environment is essential. Also, risks are involved in any business, and to handle them, more insights on business operations must be obtained. For example, business auditors need to obtain good “understanding of an organization's operations to perform risk assessment” [47].

Mariana Man and Liana Gadau [34] introduced a model for profit and loss analyses and the disadvantages of profit and loss analysis were summarized. The profit and loss analysis are widely used all over the world as it is the simplest way to decide on any investment. However, the profit and loss analysis doesn't help in many situations. Although profit and loss analysis could give positive signs, the lack of knowledge of business operations can lead to uncalculated risks that could result in serious challenges for achieving business goals. Also, considering profit and loss only while renewing vendor contracts might result in consuming extra resources to negotiate the prices, and even losing the contract in some cases. Moreover, there is no measure for "the performance of the management in achieving the enterprise functions" [34].

As the CAV is a new industry, various infrastructure investments will be needed to facilitate their operations. Defining the enterprises that will form the CAV ecosystem is a challenge that needs to be addressed. New business entities will be born, and the existing business entities will experience new roles and changes in existing relationships. Risks involved in the new business can't be identified and managed without business understanding of the industry ecosystem, which consequently, empowers business owners to decide on risk management strategies. The road owner will need to calculate the business benefits and the risks in the case of investing in company owned RSE or outsourcing the entire operation to a business partner. A deeper knowledge of the exchanged values and how they are created and streamed is essential to assist the decision and recue the ambiguities.

On another scale, the conventional methods to decide on investments are based on business cases that study the profit and loss analysis, which doesn't provide any understanding of business operations. Also, the "As-Is" and "To-Be" business situations were previously evaluated based on conventional modeling tools such as the Value

Network Analysis (VNA), Supply Chain Operations Reference (SCOR), and e3Value; which will be discussed later. Each of those tools had limitations, and they either considered value form the cost perspective, or focused on supply chain management. Also, the study of business alternatives was very complicated and there was no clear view on how different alternatives can affect the business in the future.

Any business entity in the CAV ecosystem should know the exchanged values that would contribute to a CAV successful trip. For the road owner, CAV trip safety is related to the RSE that provides V2I communications. Many services contribute to a CAV safe trip such as Variable speed limiting, dedicated lanes, and emergency notifications. No previous attempts were made to use a modeling tool to build CAV ecosystem and assist the road owners in understanding the CAV operations.

The output of current modeling techniques doesn't support service development. The risks faced in service development include scheduling issues, requirement creeps, and employee turnover. Without proper alignment on the services' specifications, such risks will be imminent. Unified Modeling Language (UML) use case diagrams for service development can minimize those risks because they will provide alignment and referencing. The road owner will need Value-based UML use case diagrams. The current methodology is to hire UML experts and provide them with essential data such as business structure and the service architectures to produce the use case UML diagrams; a process that consumes time and resources.

1.3 Proposed Solution

The role of business modeling is to provide detailed design of the business operations and help business owners define how value is created and exchanged in the business ecosystem. Value Delivery Modeling Language (VDML) is the only business modeling tool that considers value creation and value exchange in the business ecosystem. The Value Management Platform (VMP) tool was used to build the ecosystem of the CAV. The focus was on the road owner as the organization under study, while other entities were defined as business partners and customers. Moreover, other business models were defined for the Internet Service Provider (ISP) and the RSE as well to have total understanding of the ecosystem. The model was first built for the "As-Is" business situation for the road owner and the business partners except for the RSE provider. The impact of customer satisfaction was added to the system based on the Net Promoter Score (NPS), where promoters were expected to increase the business year over year revenues.

To assist the decision maker on future investment decisions, the VMP model was used to predict the performance of the Road Owner business for CAV readiness with two scenarios. The first scenario assumed that the road owner will outsource the RSE business. The data used assumed that the CAV business will start based on the available financial data of 2018. Business model Cube was presented for the road owner and it summarized all the model parameters and gave the business owner more understanding of the values exchanged in the ecosystem. The Business Strategy Map showed the competencies used and the allocated costs, and it also showed revenue generation and profit. Value Stream Mapping defined the services that add value to the customer and how they are created through the ecosystem. All the VMP graphical notations are extremely important for the business owner to clear any ambiguities about the value creation and the value streaming into the ecosystem, consequently, business owners can have a better risk identification process. The Basic Risk Identification involves analysis that are enriched by the VMP ecosystem, moreover, the Detailed Risk Identification includes the business owner to use data that is integrated in the VMP model. The Ecosystem, VSM and Business Model Cube provided new insights which reflected broader understanding of the incorporated risks which would save the business owner's time and resources. Finally, the VMP model supplied essential information for the Risk Validation; which is crosschecking the risks against scope.

The second scenario assumed that the road owner will decide to invest in the RSE as part of the road owner business. The model projections were compared to show the cost on both cases and the expected revenues. It is up to the business decision makers to choose which alternative to use based on their vision and strategy.

To facilitate service development based on the VMP model built for the road owner, a tool has been developed to produce VMP-Based UML use case diagrams. The tool targeted the services component of the model in JSON format and converted it to XML 2.0, which is was then fed to PlantUML tool. UML use case diagrams provided clear description of the services offered to the CAV; consequently, no extra resources will be needed to generate UML use cases, and less service development risks will be encountered.

1.4 Assumptions

As the CAV business is still in development, some assumptions must be made to build the CAV ecosystem. Some detailed assumptions will be mentioned in the body of the research; however, the main assumptions are:

- The ecosystem is based on the use of Road Side Equipment (RSE) as it is widely used in North America. However, the discussion of RSE vs. 5G for

CAV operations is still in effect, and there's a possibility 5G and RSE integrated or 5G only will be used in the future.

- The estimated cost of the RSE was determined by the cost of construction and maintenance of RSE in the U.S.A at the present time. In the near future, these numbers might change when attempting to roll out those stations in Canada
- The business partners in this model are based on ARC-IT Version 8.2. More enterprises and more functionality might arise in the future when the CAV level 5 are launched.
- The amount of flexibility in the VMP makes it feasible to derive business alternative models from the base model and consequently reflect those changes on the ecosystem. Future enterprises and enterprise interactions can be updated in the constructed model.
- The forecasted number of CAV trips on the private road was determined by investigating the current revenues of Toronto's private road 407ETR and by contacting the 407ETR management team. Also, the cost of Traffic Management Controller (TMC) and ISP connections were reported by 407ETR.
- The RSE provider, which is a thing of the future, was forecasted to aim for Earnings Before Interest Tax Depreciation and Amortization (EBITDA) of 40%, which is the average EBITDA margin for IT industry in North America.

- The model is built using the 2018 road owner financial data as it is the latest available data.

1.5 Scope

The scope of this research will cover the business model creation for the road owner as part of the CAV ecosystem, and the UML use case generation based on VMP modeling. The VMP will be used for that purpose. The business decision of investing in RSE or outsourcing it will be discussed in that context to assist the decision makers in deciding on future investments.

The scope will cover the following:

- The ITS packs a lot of information that cover many aspects of road management including, for example, traffic control and traffic analysis. Only ITS information that is related to the CAV operations from the road owner perspective will be included in this research.
- The exact services that are used by the CAV and the traveler are not detailed in the business ecosystem of the VMP model. The model considers the business interactions and the business stream mapping between business entities. The services will be briefly discussed in the value stream mapping section.
- The CAV operations include many communication modes. The V2V, V2I, V2P; and all of them can be summarized as V2X. The RSE is concerned with the V2I only, other communication modes infrastructure equipment will not be included in this research.
- 5G communication for CAV operations is not in the scope of this research.

- The model is focused on CAV form the road owner perspective. All enterprise interactions and value exchanges are based on the CAV operations.
- Original Equipment Manufacturer (OEM) and all related innovations and CAV parameters are not included in this research.
- The business model enterprise interactions are based on the ARC-IT Version 8.2.
- The ISP cost of connection is based on the RSE usage, the cost for 5G usage is not included in this model.
- UML use case diagrams based on XML 2.0 are used in this research.

1.6 Contributions

The research will add the following contributions:

1- A methodology that allows business analysts and researchers to build a VMP ecosystem for CAV operations from the road owner, RSE, or ISP perspective, which will help decisions makers take more sound decisions and reduce operational risks.

2- VMP model to calculate the business values exchanged in the CAV industry, and the model will be used to assist the decision makers in the Road Owner business in making sound decisions about future investments and assist the road owner in risk identification.

3- A model for internal decision making in the business that allows linking the outputs realized for the VMP model into a Case Diagram UML that will assist internal company developers into designing the related systems that support the CAV operations and reduce service development risks.

1.7 Research Methodology

Information Systems (IS) research guidelines [14] were followed through this research. More details can be found in Appendix B. The requirements were to have a descriptive model for the CAV operations from the road owner perspective. The model should consider value creation and value exchange between business owner, partners, and customers in order to have a clearer description of the ecosystem and the value creation to assist business owners in their future business decisions, and help corporates reduce the operational risks through a value-based risk definition. The “As-Is” situation was studied, which is the current situation before investing in making the road CAV ready. The model was validated against existing data. Then, the “To-Be” model was constructed to study the business projections for the road owner after CAV investment both for RSE outsourced and for RSE invested by the road owner. The research was conducted based on the design science IS research framework suggested by Hevner et al’s work on design science [14]. The environment is defined by the CAV ecosystem and it contains the people, organizations, and the new artifacts that serve the business need of the Road Owner, which is to avail CAV operations on the road. The artifact under study is the innovated VMP model constructed for the CAV ecosystem and focused on the Road Owner, and the tool that produces the UML use case diagram. The problem that the model solves is the need for the business owners to understand the value creation and value exchange in the ecosystem, which in turn helps them to define the risks and choose proper risk handling strategies.

As discussed in Appendix B, there are five design evaluation methods. The Observational method is aimed at studying the artifact in different projects or in its business environment, which reflect field study or case study. As the VMP model in this research is innovated for a future business, this observational evaluation cannot be performed. The Analytical method requires analytical metrics to evaluate the artifact mathematically. Analytical methods contain static analysis that studies the complexity of the artifact, architecture analysis which determines if the artifact fits the existing structure, optimization which focuses on the artifact behavior, or dynamic analysis that study the performance of the artifact. The analytical methods are not suitable for the VMP model of CAV operation as the knowledge offered in the model is mainly for assisting the business decision makers and increasing the business awareness of value creation and value exchange. Such qualities cannot be mathematically evaluated.

The Experimental method requires an existing environment to test the artifact, or a simulation or test environment. As this research is studying future situations, and as there's not full CAV operating environment constructed yet, this method is not fit for this research. The same challenge faces the Testing methods which perform functional testing or structural testing, both need a working environment to be run. The fifth method is Descriptive which include Informed Argument that uses relevant research to showcase the artifact's utility, or Scenarios which build scenarios to demonstrate the artifact utility. "Descriptive methods of evaluation should only be used for innovative artifacts" [14]. In this research the Descriptive Scenarios method is used to study the design of the VMP model for CAV.

Chapter 2

Business disruptions have become more evident in the latest decades. This was due to the rapid advancement in new technologies and the realization of innovation as a key component to business continuity. The Internet of Things (IoT) applications are gaining more attention and causing a huge shift into the way that companies approach their customers. The business innovations in all industries are in the focus of any investors.

For business owners, it is important to identify the operational risks to decide on the risk management plans. Risk identification requires deep understanding of the operational functions and how the business interacts with partners and customers. It is also important to understand their customers' feedback on the service or product they are receiving. Their feedback in the form of net promoter score should be integrated in their business modeling plans to account for its impact on revenues and business continuity. On another hand, a basic knowledge for the CAV industry include the CAV six levels of automation as well as CAV communications with other vehicles, infrastructure, and pedestrians. Business modeling techniques are reviewed in this chapter to show the evolution of business modeling that lead to VDML. Also, a VDML example and a VMP example are also discussed.

2.1 Enterprise Risk Management

While enterprises strive to achieve their goals, they encounter operational challenges which could be avoided if proper risk assessment and risk management were performed. The Enterprise Risk Management (ERM) had many definitions, however it was defined by Lam (2000) as the "integrated framework for managing credit risk, market risk, operational risk, economic capital, and risk transfer in order to maximize firm value." [35].

The main idea is to integrate all possible risks that would arise to have a clearer anticipation of the future of the enterprise. In any business cycle, risk management should be applied all through the cycle, this is referred to as a continuous "evaluation of the nature and extent of the risks to which the company is exposed." [36]. This requires good knowledge of the business ecosystem, the partners, and the values exchanged between the business owners, the partners, and the customers.

2.1.1 Risk Identification

The first step in risk management is to identify the risk. Project Management Institute (PMI) has identified the procedure for risk identification. The main steps to identify the risks were summarized in [37] as follows:

1. Basic Identification

   The first step in this to perform a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis [55] which will identify the basic knowledge about the enterprise. The second step is to gather all data from lessons learned in previous business endeavors by the enterprise or, if possible, by similar enterprises or partners in the same industry.

2. Detailed Identification

   Once the risks are defined, a deeper investigation is needed to further understand the risks and define the proper way to manage them. The first technique is to perform interviews; and a key aspect is to define whom to interview and what data needs to be collected. The input of industry experts and business leaders is essential as well. Assumption analysis assumes that if an assumption fails, it turns into a potential risk. Other techniques such as the Delphi technique and brain storming can be applied, and they are discussed in more details in [37].

3. Expand the list

   In this step, the risks are organized in a checklist and proposed solutions are also recorded. The risks can also be categorized into clusters that represent each operational aspect, or department, and the relative risks.

4. Validate against the scope

   After the list is finalized, it must be cross-checked with the Work Breakdown Structure (WBS) which describes all activities in the project.

2.1.2 Risk Management

The risk management techniques vary; however, they were summarized in [36]. The main risk management strategies are:

1. Accept the risk

   For risks identified as small risks, it sometimes is better to accept that they might happen and deal with them if they do. If such risks are accounted for, they will consume a lot of resources to prepare for their occurrence or have a mitigation plan for them.

2. Avoid the risk

   Risk avoidance is about changing the plans to avoid the risk occurrence. This is done when the risk is expected and well known. Altering the plans will affect the resources, however, it will totally remove the risk.

3. Transfer the risk

   Transferring the risk could be done in projects where many entities are involved. This is done by agreement between the parties to define which entity will handle which risk. This is typically the case if a certain partner will produce a certain outcome, and that outcome might generate risks that could affect the entire project; in that case, that partner will be responsible for those risks and this will be signed off.

4. Mitigate the risk

   This is the most common and simplest technique used for risk management. Once the risk is identified, the proper actions are taken to prevent it from happening and contingency plans are made to handle the risk occurrence. A good example for that is giving the employees the needed training to perform certain tasks.

5. Exploit the risk

   In some cases, risks could have positive impact on the project, and in that scenario, the management will capitalize on the risk occurrence to obtain maximum benefits.

All the mentioned risk identification and risk management techniques are subject to the decision of the project manager or the business decision makers. This means they first need to clarify all the ambiguities in the business cycle to make sure they have identified most of the risks that could affect the enterprise performance.

2.1.3 Service development Risks

Software service development risks have been investigated by many scholars. Jiang and Klien investigated the main risk factors that cause software development delays or failures [51]. "*Lack of clarity of role definitions*" [51] was one of the main risk factors that threaten the software development projects. Other factors were related to managing the user experience [52], whereas '*not meeting user expectations* and *misunderstanding of the requirements"* were two main risk factors that affect the success of the software development. Risk factors that affect the software quality were studied and summarized [53]; where "*low people qualities"* were found to have negative effect on the overall quality of the project. Boehm (1991) defined ten software risk items that affect the software projects, including "*developing the wrong functions and properties*, and *developing the wrong user interface*" [54].

The software service development risks can be summarized as follows:

- Wrong estimation of development time
- Requirements' changes and scope creeps.
- Employees turnover, which imposes the need to realign new employees on the development goals.
- Wrong effort distribution over the project time.
- Conflicts at integration.
- Rushing the design process.
- Gold Plating, which is adding features that are not required.
- Operational risks that were not accounted for in development.
- Reduction of project scope due to excessive budget.

- External unavoidable risks, for example, changes in government laws.

The service development risks can be reduced by proper alignment between the enterprise point of view and the development teams. Proper documentation and referencing of the service parameters will not only achieve intra company alignment but will also help project managers minimize the risk of employees' turnover and the risk of developing something that is out of scope, which would lead to unsatisfied customers.

2.2 Net Promoter Score

As per Hanson [32], Net Promoter Score (NPS) was presented by Fred Reichheld in 2003. Prior to NPS, many theories were introduced to understand customer satisfaction. Some of the most famous theories were the *Dissonance Theory*, the *Contrast Theory*, the *Expectancy Disconfirmation Paradigm*, and other theories that are discussed in detail in [33] and the *Discrepancy Theory* that is discussed in [12]. All older theories, including modified versions of them, used complex models to try to explain and quantify the customer satisfactions. The theories mainly used lengthy questionnaires to find the reasons why a customer would perceive the product or service offered as acceptable or not. The questionnaires were to pin point specific reasons for the customer's opinion. Not only were the process complicated and difficult to run on customers, but it also consumed resources to collect and analyze the data.

The NPS by comparison is a very simple technique, and it has been greatly appreciated and used in many organizations. It is based on a simple straight forward question asked to the customers: *How likely are you to recommend the service to your family and friends?* Then the customer must choose a number from 1 to 10. The Promoters, who will choose 9 and 10, are the customers who will likely recommend the product or service to other people whom they know. This means that they are very happy with the product or service and perceive a lot of value in it. In this case, the Promoters will work as brand ambassadors. The Passive customers are the ones who will choose 7 or 8. These are the ones who may be satisfied but will not go for promoting the service to others, or they are not decisive about the product or service. The Detractors are the customers who will choose any number between 1 and 6. This means they are angry with the product or service and don't perceive the offered value. They are likely to talk to other people and tell them about a bad experience and they will tell everyone not to use the service or purchase the product. The net promoter score is: *% Promoters - %Detractors*. Although the NPS is a simple tool, it lacks the details needed to know why customers chose to be promoters or detractors. Some companies combine the NPS question with other questions from previous techniques to try to get the best of both worlds.

2.3 CAV Levels of Automation

In the year 2014, the Society of Automotive Engineers (SAE) issued *Standard*

Table 1 [5] Automation Levels for Vehicles

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

J3016 that defined 6 levels of automation that would be used by all stakeholders in the CAV industry [6]. The 6 levels are based on how much automation of the driving process itself is given to the vehicle.

2.3.1 Level 0, No Automation

This is the level where absolutely no automation is applied. The Driver takes full control of the vehicle, he controls the speed, the steering, and reads the meters himself to direct the vehicle to its destination. This level is easily understood if we think of older cars where no GPS equipment were available and with no cruise control.

2.3.2 Level 1, Driver Assistance

In this level, the vehicle can handle some functions such as steering and adaptive speed control, but only in certain modes such as self-parking features, or lane change assistance. The driver must always be aware of the environment and both traffic and road conditions.

2.3.3 Level 2, Partial Assistance

In this level, the driver is still in full control of the vehicle but some functionalities or driving assist features are controlled by the vehicle itself. The driver must always be aware of the traffic and road conditions. A good example of such assist feature is the adaptive cruise control, or traffic cruise control; which takes into consideration the distance to other vehicles. Another example is the automatic steering on lane change, but with restricted speeds. Level 1 is existing in many commercial cars already.

2.3.4 Level 3, Conditional Assistance

The vehicle takes over environmental Monitoring, but the driver is a necessity. The vehicle can handle environment monitoring, acceleration, deceleration, and braking. The driver must take control whenever it is required. According to May [7], the Audi A8 was of the first level 3 production car. The car can perform all control tasks of starting, steering, lane control, acceleration, and braking up to the speed of 60km/hr. if the system reaches its limits, the driver is requested to take over the controls.

2.3.5 Level 4, High Automation

The vehicle takes care of everything, controls the steering, and continuously monitors the environment in many different situations. The driver can take his eyes of the road and enjoy the ride. However, the driver can choose to drive the car and switch off the autonomous mode, or in case of any safety ambiguity, the vehicle can ask the driver to take over, and if he doesn't, the car will continue driving itself. "the Google/Waymo self-driving vehicle has been operating at the level of autonomy for a few years." [7].

2.3.6 Level 5, Full Automation

This is the level where the vehicle takes full control of the driving process and doesn't need human interference at all. The cars in this level don't need to have a steering wheel or pedals. Many manufacturers have concept cars in this level.

2.4 CAV Communication

2.4.1 V2V Communication

To achieve efficient and safe operation of the CAV, communication between vehicles is of utmost importance. When CAV communicate, they exchange important data packets containing the road utilization, speed, obstacles, and other important info. When vehicles in the proximity of each other communicate they create an AD-Hoc network, which are referred to as "Vehicular Ad-Hoc Networks (VANET)" [8]. The main challenge with VANET is that in order to communicate, the vehicles must be on the communication range of one another and this cannot guarantee continuous connection amongst the vehicles. Another technique of communication is to rely on 4G or 5G networks to make sure that all vehicles are continuously communicating together on a more holistic scale and exchange more data that would benefit the trip planning by the vehicles which are beyond the communication range with other vehicles.

2.4.2 V2I Communication

Vehicle to Infrastructure, and inherently Infrastructure to Vehicle, communication is a major milestone in CAV operations. The connection will allow the vehicles to receive important data, especially in urban areas, and will allow cities to collect CAV data for many purposes including analysis of performance, emission control, congestion management, and other factors that will help the cities add value to the life of their citizens. The standard IEEE 802.11p [10], [30] was released to regulate the communications needed for the CAV operations. DSRC uses this standard. The concept is that the On-Board Unit on the CAV will communicate with the DSRC and interchange important data on traffic lights, road conditions, and traffic conditions. Through those connections, the Traffic Management Centers (TMC) of urban areas can collect and send data to CAVs. Although DSRC is the main technology used for CAV V2I and I2V communication, it comes at a high cost for the construction of its radio networks. The future deployment of 5G networks can be the most suitable replacement for the DSRC. 5G technology can offer high data rates that can support the V2I and the I2V communications. Also, the cost of deployment is not very high as the roll out of 5G equipment will mainly upgrade current cell sites and will use the fiber optics infrastructure. The decision makers will have to decide if DSRC or 5G is the future technology for the CAV. The author in [11] suggests that they can complement each other. “DSRC is the technology that is currently predominant in the U.S. connected-vehicle market. In fact, it is prescribed by federal regulators” [9]. On the other hand, many car manufacturers, have announced that their CAVs will use 5GLTE.

2.4.3 V2P Communication

The main concern in CAV operations is safety. Commutating to pedestrians is a key factor in achieving the required safety standards. The CAV will communicate to pedestrians through their smartphones. The pedestrians' safety is divided into two categories: sensor based, and communication based" [8]. The sensor based relies on having a line of site with the pedestrian, where the communication based allows the CV to detect pedestrians who are not in its line of site, while also, communicating data from the CAVs to the pedestrians if necessary.

2.5 Business Modeling Techniques

Many business modeling techniques were introduced over the past years. Each of them addressed a certain business aspect. "A business-friendly modelling is very helpful for business people, and also can act as a communication tool between them and technical IT people" [45]. To understand the VDML and how it adds value to the businesses, the following part will review earlier business modeling techniques, their strong points, and their relative limitations.

2.5.1 Value Network Analysis

The Value Network Analysis (VNA) applies a modeling methodology that defines the players in the system and the value interactions between them. This is defined by the "Concept of role collaboration and exchange of deliverables" [17]. Allee provided a detailed description of the VNA [17]. The model discussed the tangible assets, and intangibles as assets, and defines the roles and how value is created out of them. The main strength for this model is that it helps to view overall business units and their roles in value creation. The main drawback is that the VNA doesn't go further than defining the features of the business. It doesn't cover the value exchange or value streaming in the ecosystem.

Joe Peppard and Anna Raylander have explained the steps for creating a value network analysis of mobile network operators in the UK [41]. The first step is to define the network objective, then identify network participants. The third step is to identify the value dimensions of the network participants and how they are exchanged. Finally, the produced shape should be analyzed. The VNA example shows how value is created from partners and how it is delivered to the customer for the mobile content.

2.5.2 Supply Chain Operations Reference and Value Reference Model

Supply Chain Operations Reference (SCOR), presented by Bolstorff and Rosenbaum in [18], is usually used for the design of supply chains. The *Value Reference Model* (VRM), presented by Mercer et al in [19], is more focused on automated business processes. In both models, all value chain activities are compared to predefined standard business models, consequently, the performance can be explained and evaluated. Those approaches are mainly focusing on business elements such as supply chain networks, organizational interactions, and organization resources. There's no focus on the value delivered to the customers or the contribution of each business segment to the achievement of this value. More information about the SCOR process and the SCOR steps can be found in [42].

SCOR was applied to two companies that need to invest in ICT [43]. The SCOR has four parts; process, performance management, implementation, and participants. The process has three levels; process type level, process category level, and process element level; and each level is based on the previous level.

2.5.3 Lean Value Streams

Although *Lean Value Streams* was introduced by Rother and Shook [19], which is earlier than previously discussed models, it considered the value concept. The approach was originally designed for manufacturing facilities, and it considered analyzing all material flows and manufacturing processes to reduce any waste, and hence, maximize the value delivered to the customer. The approach focused on the value delivery to the customers in terms of execution time, however, the value itself and how the customer perceives it, was not addressed in this model. An example of the lean value stream was presented by Lasa [44]. It consists of five phases that can be summarized as "(1) selection of product family; (2) current state mapping; (3) future state mapping; (4) definition of working plan; and (5) achievement of working plan" [44]. It also studies the current state and the future state, and a value stream map is built for each of the two states.

2.5.4 Resource-Event-Agent

To address the economic aspects of the organizations, Hruby et al. [20] introduced the *Resource-Event-Agent* (REA) pattern. The pattern defines the main resources as the agents and describes the interactions between those agents and other resources from the financial perspective of price versus cost. The REA applications are all in the accounting area of the business. In REA, the reciprocity concept was used, which describes the mutual benefit between two business entities to receive something for exchange of something provided. This concept is adapted for VDML, yet, REA didn't address the broader concept of value creation or value delivery.

2.5.5 e3Value

e3Value was the most famous modeling technique that address the value interactions in the e-commerce era. Introduced by Gordijn and Akkermans [20], "the e3-Value is an ontology-based methodology for modeling and designing business models for business networks" [21]. The e3Value also includes graphical notations. To analyze the business interactions between separate independent enterprises, each enterprise as a separate financial entity is recognized as an *Actor*. The actors have values exchanged between them in terms of products or services, and like the REA, the concept of economic reciprocity is used. e3Value provides economic quantitative analysis in terms of cost and profit, moreover, it provides qualitative analysis by assuming what-if scenarios for business transactions between the actors, and it also considers the forecast of each of the business utilities, which adds great value to the understanding if the economic performance in the business ecosystem. The cost of the product or service and its sales price are clearly determined through the in-depth definition of each deliverable. The in-depth definition of different business what-if scenarios gives insights about which business decisions to make. The concept is also adapted in VDML, however, e3Value only considers cost.

E3Value was used to investigate the call charging and fraud attempts for mobile operators in [46]. The model describes the healthy situation from the network operator's perspective, and the fraud possibility from the customer's perspective. The interconnection cost between two service providers is illustrated and the users' roles are also displayed. The model was built for different scenarios to study the fraud possibility and eliminate it.

2.5.6 Capability Analysis

The previously discussed models and methodologies didn't consider the capability of any business. The *Capability Analysis* uses the capability map to define each capability needed by the enterprise to deliver the required results. The process also includes the analysis of the performance for each capability and its importance for delivering the desired results. The DNA of each enterprise is mainly "what" it does, the way things are done, the "how", might change based on many factors in the business ecosystem. The capability analysis focus on what the business does. the analysis starts by defining the capabilities and then defining several levels of details, if needed, and the outcome of this is the *Capability Heat Map*. Such an analysis will help companies focus on their main activities and if necessary, outsource other functions or capabilities. Also, it helps the workforce of an organization to understand what needs to be done and increase their focus on the capabilities they have.

One logical consequence was that some approaches combined both capabilities and value chain analysis to have a broader view on the business processes and combine all factors to give more insights for decision makers and help align corporate goals. The capability map is a very powerful tool for enterprise alignment within the organization which is essential to increase the focus and create synergy. It also helps to define what the organization does and how to do it, and it is very useful when combined with supply chain analysis. The limitation of this method is that heat maps are not enough to realize the value creation in the organization.

Table 2 [48] shows a comparison between business modeling techniques prior to VDML.

Table 2 [48] A comparison of earlier modeling techniques

Model	Advantages	Disadvantages
VNA	- Role Collaboration - Tangible and intangible deliverables. - Business ecosystem.	- The model is limited only to roles and deliverables only. - Any other details are defined as formatted text.
SCOR	- Supply chain Activity modeling. - Modeling of deliverables and resources. - Integrated approach.	- No focus on value propositions. - Scope is limited to a single process.
LVS	- Manufacturing materials and information flow. - Definition of added value and waste. - Linking value streams.	- Measures business cycles in manufacturing only. - Doesn't support business simulation or detailed analysis.
REA	- Accounting perspective. - The concept of reciprocity. - Modeling of resources and resource stores.	- Focus only on economic value. - It provides an abstract price and cost model where levels of abstraction are not supported.
E3Value	- Supports quantitative what-if scenarios. - Supports complicated aggregation of measurements.	- Focuses only on cost and revenue. - Just a complex computation model with no broader concept of value.
Capability Analysis	- Capability definition into value chain.	- Provides partial parts of a business model.

In all models prior to VDML, the value concept was not investigated in full. The models were aiming at exploring other areas of the business ecosystem, such as value chains or economic performance. Combining some of the models to grasp a better understanding of the organizational behavior would also result in some gaps that are not covered. This necessitated the need for introducing a new modeling language where all the strengths of previous models were considered, as well as the realization of value and value delivery. Consequently, the VDML was introduced.

2.6 VDML

The classification of enterprise objects based on enterprise layers and sub-layers is shown in Table 3 [49]. The value is a sub-layer of the business layer. We note that the risk object is categorized under the value sub-layer, which reflects the importance of the value concept in the risk management process.

Table 3 [49] Classification of Enterprise Objects

Enterprise Layers	Sub-Layers	Meta Object Class Types
Business Layer	Value	Expectations, Value Propositions, Value, Strategy, Goal, Objective, Plan, Quality, Risk, Security, Control
	Competency	Organization, Organization Competency, Enterprise Capability, Actor, Enterprise Object, Product
	Service	Service Contract, Business Service, Service Flow, Service Channel
	Process	Process, Gateway, Process Flow
Information Layer	Application	Application Component, Application Function, Application Service, Application Object
	Data	Data Component, Data Object, Data Table, Data Channel
Technology Layer	Platform	Platform Component, Infrastructure Device, Platform Service, Platform Rule, Platform Device, Platform Channel
	Infrastructure	Infrastructure Component, Infrastructure Device, Infrastructure Rule, Infrastructure Channel

Founded in 1989, the Object Management Group, Inc. (OMG) is a non-for-profit computer industry standards consortium that provides open membership and is aimed at the production and maintenance of computer industry specifications for interoperable, portable, and reusable enterprise applications in distributed, heterogeneous environments [25]. "Membership includes Information Technology suppliers, end users, government agencies, and academia" [22]. Value Delivery Modeling Language was introduced by OMG in 2009 [25]. The main purpose was to integrate existing business modeling methodologies, but more importantly, to focus on the creation and the exchange of value.

The main differentiator in modern business environments is the value. Enterprises have evolved from pushing their products to customizing their products through marketing research. Customers, on the other hand, perceive the importance of each product based on how much value it adds to them. Thus, the concept of value has become essential, and each enterprise needs to understand how value is created and exchanged between its business partners, and how it is delivered to the customers. The VDML main purpose is to "provide a standard modeling language for analysis and design of the operation of an enterprise with particular focus on the creation and exchange of value" [22]. The decision makers in any organization need to have more insights about their company, their products or services, and their business partners and vendors. It is extremely beneficial for them to build a business model that incorporates all these players and focus on how value is created and exchanged, and consequently, assist them in sound decision making. The business decision makers, usually the C-level, need to know the value of each business aspect and how much it contributes to the final product or service. This is usually done by having "As-Is" and "To-Be" scenarios that will be modeled to forecast several investment choices and give clear insights for business decision makers.

2.7 VDML Examples

VDML and VMP have been used to help a lot of decision makers realize how the value is created and delivered. As mentioned earlier, the VDML concept can be applied to any business, because any business will have values exchanged. Two examples will be reviewed to showcase the flexibility of the tool and its application two different fields: healthcare and recruitment services. The healthcare example was constructed by an earlier version of the NEFFICS VDML tool, it shoes the basic concept and the expected outcomes, however, on the HR recruitment example, a recent version of the VMP tool was used. This will add value to the understating of the evolution in the VDML realm.

2.7.1 Healthcare Example

The healthcare example is discussed in detail in [23]. The Business Model Innovation Cube, and its sides represent six dimensions. These are the same dimensions that will be used by VMP to produce the road owner business cube for the CAV ecosystem. The first dimension is the Value Propositions, and in this case, it contains one value propositions that is offered to the customers. The Customers dimension contains the clients, or the patients, who will receive the values offered by the business owner or service provider. In order to deliver the value, the provider needs to have business partners, use own capabilities, and perform related activities. The capabilities needed are the competencies that the business owner or service provider have to offer the value to the customer, while the related activities are the efforts performed to deliver the values. The Value Formula contains the offered value, and a seventh dimension is the relations that link all those dimensions together.

To further understand the BMI Cube, the VDML diagram illustrates the direct relations between the different players in the business ecosystem. The diagram is also referred to as Role Collaboration Diagram. The diagram shows the connections between the customer, the business owner or service provider, and the business partners, moreover, it also shows the exchanged values between different players in the VDML diagram. The diagram is viewed from the perspective of the hospital as the healthcare provider. It's important to note that for the analysis of different business owners in the ecosystem, a new VDML diagram should be constructed from the perspective of that specific business owner.

The Hospital exchanges values with the doctor's office as a business partner; and the client, which is the patient. In [23], other diagrams can also be generated to explain the exchanged values, such as the value proposition diagram which shows the values exchanged between the players, and this is similar to the diagrams generated by the VMP tool. Also, the VDML Activity Network Diagram can be generated, which focuses on the activities that are carried out to exchange or deliver the values.

Another diagram that helps to further understand the business relationships and the value streams is the VDML Capability Management Diagram. The diagram shows how the capabilities are managed to deliver the value to the customer. In this diagram, the Maternity Ward is the main value under investigation. All other internal values exchanged between the different players are choreographed to finally deliver the maternity ward value to the customers. The VDML can define the values that are exchanged and integrated to deliver the maternity ward value margin to the customers. Which in turn makes it very clear to decision makers to define the added value of each value margin. The value margin is affected by value impacts from different players in the ecosystem. Those impacts are value propositions that are exchanged by the players in the ecosystem. "A "Value Margin" can be established, in this example for the Hospital, which is the result of providing and receiving Value Propositions" [23]. The healthcare example shows the capabilities of the VDML and how it provides more insights than earlier tools. In the following section. The HR example will provide the VMP tool and will show how advanced is the VMP with respect to the earlier VDML systems.

2.8 VMP

VMP model was built to answer to many business needs that were not addressed by earlier VDML versions. The OMG requested new development of VDML tools and as will be discussed later in the recruitment example, it helps build an ecosystem that includes all the players. The first step is to define a business owner, and then define the business partners and the customers. The business model cube shows the Competencies, Activities, and Values. The cube is where the business values are represented, and its respective costs are inserted for detailed business analysis. All the exchanged values are represented in the cube and they are aligned to the Business Model Ecosystem. Once the Ecosystem is defined and all the services are mapped, they show up in the cube and the business modeling expert can process them as required.

2.8.1 Recruitment Agency Example

Ruben Lovenweent in [24] has applied the VMP tool on a recruitment company. The case was to study the “As-Is” and “To-Be” situations for Studaro which is a company that focuses on connecting fresh graduates to organizations. As Studaro is the business in focus, the ecosystem is built bearing in mind that Studaro is the only company that will be studied. The ecosystem contains all the business partners that Studaro needs to complete a successful recruitment job and it also includes Studaro customers. With every connection to the business partners or the customers, the exchanged values are shown. The whole system is built based on mutual exchange of value.

As will be discussed later in the CAV VMP model, other companies, considered as business partners here, can also have their own business models built using the same ecosystem. In that manner, the ecosystem will be more complicated and will include more players. VMP is much more informative than the earlier version of VDML used in the healthcare example. It makes it clear for the decision makers to visualize the connections to business partners and the exchanged values.

The strategy map was originally introduced by Kaplan and Norton (2004) and it was requested by the OMG for the VMP as part of the alignment to all existing business models and to add the Value dimension to it. The strategy map in [24] shows the competencies used by the business owner and business partners in order to deliver the required values to the customers. All the costs are presented in the value stream and they integrate into the main cost for the process which is represented in the business value and along with other costs and revenues feeds into the profit margin.

The aggregated view of revenue and cost structure was generated. It could be easily understood how the profit margin is achieved and how all the activities aggregate. The tool also provides profit projections. Figure 2 [24] shows the projection of the profit and the profit margin over year 1 and year 2. Such projections are particularly important for business decision makers as they provide them with the data that they need to decide on new business ventures for their organizations. Other curves could be produced for other info such as cost and profit or cost and revenue, etc.

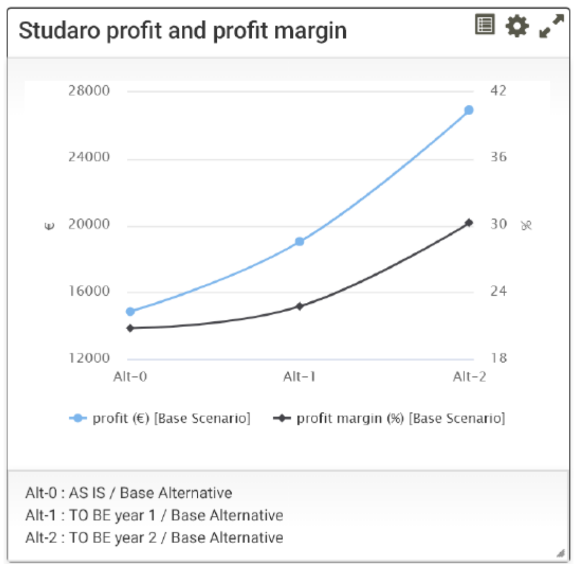


Figure 2 [24] Studaro profit margin

Chapter 3

Fagnant and Kockelman predicted the CAV to have positive impact on safety, traffic operations, and change in travel behavior [49]. For the safety part, the expectations were that CAV will be safer than human drivers if they have good recognition of objects on the road and can identify pedestrians. When it comes to traffic operations, the CAV must adjust its speed based on the congestion or blockage on any lane to have smooth breaking. Also, the CAV is expected to have more efficient lane control and lane changes. The International Risk Governance Center (IRGC) investigated the risks and opportunities of CAV operations and suggested that new business models will arise and that the main actors in the transportation industry will see changes in their current roles [50]. The report also stated that pilots are needed as soon as possible to increase the confidence level in CAV operations. One of the proposed questions in the report was "What are the technologies, innovations and strategies for managing the risk?" [50]. The services provided by the road owner answer to many of the requirements for CAV operations. However, a business model is essential to understand the CAV business environment to perform risk identification.

In this chapter, the suggested step-wise approach for building the CAV ecosystem by VMP tool is discussed in detail. This methodology will be the basis for future research in the area of building a VMP model for a CAV ecosystem and focusing on any business entity. This is followed by a discussion on ARC-IT Version 8.2 that is issued by U.S, DOT and it is the reference for the service architecture of CAV. Roles of business entities and related activities in the CAV ecosystem are also covered in this chapter, and the VDML version of the model is also discussed to showcase the added value of VMP modeling.

3.1 Step-Wise Approach

Future study of CAV systems from the ITS or Road Owner perspective will be needed as many elements of the ecosystem are still unknown.

The following procedure can be used as guidelines for the research of the road owner business in the context of CAV ecosystem.

3.1.1 Study the ARC-IT Version 8.2

a. Read the ARC-IT Version 8.2 history.
b. Understand the contents of the standard in terms of Connected Vehicles and associated types of connectivity, System Architecture, The Approach taken to develop the CAV architecture, The system viewpoints, and System security.
c. Review the relevant services in the applications part of ARC-IT Version 8.2 in terms of service definition and functional summary.
d. Review the service requirements and service physical diagrams.
e. Review the ARC-IT Version 8.2 enterprise view and define all business entities and how they communicate.
f. Summarize all the enterprise interactions between all business players for all selected services, define all of them in one table.

3.1.2 Reflect ARC-IT Version 8.2 on VMP tool

After summarizing the data from the ARC-IT Version 8.2, the final data is to be constructed by using the VMP tool in the below manner.

a. Initiate the plan and assign a plan name.

b. Once the plan is created the first phase box will be displayed. Decide on how many phases are needed. Usually, the phase is a business cycle, it could be a fiscal year or a shorter period depending on the type of business.

c. Based on the summarized data from ARC-IT Version 8.2, start constructing the Ecosystem of the business. The business owner, business partners, and customers are defined in this part.

d. Construct the Value Stream Mapping for the first phase.

e. Define the Business Strategy Mapping.

f. Initiate the Business Model Cube, and into it define the costs and revenues.

g. Define Subsequent phases based on business forecasts.

h. Validate the model against actual data from previous years.

i. Generate all the graphs for the projection of the business plans over the "To Be" years.

3.1.3 Generate UML use case diagram

Use the delivered tool to generate UML use case diagram

a. Extract the (.vpk) file generated by the VMP. The result is a JSON format of the business model.

b. Run the tool to generate XML 2.0 file format that can be used by the UML drawing tool.

c. Import the XML 2.0 file to a PlantUML tool to generate the use case diagrams.

3.2 ARC-IT Version 8.2

The U.S. DOT was established in 1967 to make sure that the transportation systems are safe and efficient. As per the data in [31], the national ITS program plan was released in 2002. Many applications were released in the following years such as blind spot detection and first forward collision warning system. The proof of concept for V2V and V2V was conducted in 2008 and the Google self-driving car project started in 2009. Recently, the ARC-IT Version 8.2 [27] was released, and it details the connected vehicle standards.

The ARC-IT Version 8.2 considers four viewpoints to describe the CAV ecosystem terms of enterprises and players and how they communicate and integrate to deliver the services. The viewpoints are enterprise, functional, physical, and communications. For VDML considerations, the enterprise view was the most suitable to define the players needed in the ecosystems. Although the enterprise view clearly describes the different enterprises and personnel needed to create an deliver the service, it doesn't have any value creation considerations. It also describes the ecosystem per service. In order to create the VDML ecosystem, careful consideration was needed to understand the ARC-IT Version 8.2 enterprise viewpoint, integrate the services needed into one ecosystem, and display that from the VDML perspective.

VDML focus is on value creation and value streams. Referring to the ARC-IT Version 8.2 is beneficial in defining the main players per service; however, a holistic integrated view is needed to define the ecosystem for one or more enterprises. As this research is mainly concerned with Road Owners, the VDML ecosystem needed to be constructed from the road owner perspective. In other words, we needed to define who the business partners are from the road owner perspective and their collaboration from value creation and value steaming viewpoints to deliver certain services to the customers, which in our case are CAV, driver, and traveler. One other very important consideration is that in VDML, the relationships between the different players in an ecosystem must be defined based on business connections, where monetary values and non-monetary values must both be considered.

To achieve this, the ARC-IT Version 8.2 viewpoints were thoroughly studied for the desired services, then they were integrated to create the ecosystem from the road owner perspective to deliver those services to the CAV on the road. The selected services were Dedicated Lanes, Variable Speed, Traveler Info, and Emission Data. The integration revealed that although many business entities are collaborating to deliver the services, there's a certain degree of correlation that defines the main entities from the CAV perspective. Those entities are the ones that are in direct contact with the Road Owner such as the RSE, TMC, and ISP provider.

Tables 4 and 5 show the integration of all enterprise players and services in ARC-IT Version 8.2, and what is expected between them. The ARC-IT Version 8.2 enterprise view point assumes different types of relationships between the business entities in the model. As mentioned earlier those relationships could be formal coordination, informal coordination, roles, relationships, or information flow. The first type of formal coordination is *Application Usage Agreement*, where one business entity owns an application and gives permission to another entity to use this tool and its applications. We find this type of relation in many parts of ARC-IT Version 8.2, for example, the vehicle OnBoard Equipment (OBE) Owner also gives permission to the driver to operate the Vehicle OBE. An example of

Informal Coordination is the *Expectation of Information Provision* as in the case between the RSE Owner and Vehicle OBE Owner. Also note the *Expectation of Data Provision* where the RSE owner is receiving this from the Vehicle OBE Owner. Another type is the *Role* and is seen in *Operations Agreement*, where one entity owns a device or an application and gives permission to another entity to operate it on behalf of the owner.

Figure 3 shows the complete model for the CAV including the main and the supplementary services. The ecosystem shows the CAV as part of the smart city. The main players here are Road Owner, RSE, ISP, and TMC, where the CAV is the customer. The VMP model focuses on the Road Owner investment decisions. The main services are those associated with the CAV operations, such as the RSE and TMC data; and the Traveler Data, which includes much information integrated to provide the traveler with all needed trip data. An example of supplementary service is the mail and calendar service for the traveler, and the data exchanged with the CAV control center. Such supplementary services are not in the focus of the model when we consider the Road Owner perspective. Real-Time Data Processing is a key element in any Smart City. Reliable data is used for self-controlled machines to take the right decisions, like the case of CAV where the vehicle takes all self-driving conditions based on data collected through different channels, such as V2V and V2I data.

As stated in chapter 2, VMDL was used for business modeling in many fields. However, no attempts were made to build a VDML model for CAV ecosystem. The CAV ecosystem is a part of the smart city ecosystem, and its main connection is with the ITS system. As the ITS system has many functions, the focus in this research is to investigate the ecosystem mainly from the perspective of the Road Owner.

Table 4 ARC-IT Version 8.2 collaboration

	Vehicle Owner	Driver	Vehicle OBE Owner	Roadway Owner	RSE Owner	RSE Operator	ITS Roadway Equipment Owner	ITS Roadway Operator	Transit Vehicle Operator	Traffic Manager	RSE Restricted Lanes Application Provider	Enforcement	Transit Fleet Manager	Vehicle Restricted Lanes Application Provider	Transit Vehicle Schedule Management Provider	Vehicle Speed Management Assist Provider	RSE Environmental Monitoring Provider	RSE Speed Management Provider	Vehicle Roadside Information Reception Provider
Vehicle Owner		Vehicle Usage Agreement	Vehicle OBE Usage Agreement											Application Usage Agreement		Application Usage Agreement			Application Usage Agreement
Driver	Vehicle Usage Agreement		Expectation of Information Provision					Expectation of Information Provision											
Vehicle OBE Owner	Vehicle OBE Usage Agreement	Expectation of Information Provision				Expectation of Data Provision													
Roadway Owner					Service Delivery Agreement														
RSE Owner				Service Delivery Agreement		Operations Agreement	Information Exchange Agreement			Information Exchange Agreement	Application Usage Agreement	Information Provision Agreement	Information Exchange Agreement				Application Usage Agreement	Application Usage Agreement	
RSE Operator			Expectation of Data Provision		Operations Agreement				Expectation of Information Provision										
ITS Roadway Equipment Owner					Information Exchange Agreement			Operations Agreement											
ITS Roadway Operator		Expectation of Information Provision					Operations Agreement		Expectation of Information Provision	Information Exchange and Action Agreement									
Transit Vehicle Operator						Expectation of Information Provision		Expectation of Information Provision					Vehicle Usage Agreement						
Traffic Manager					Information Exchange Agreement			Information Exchange and Action Agreement				Information Provision Agreement	Information Exchange Agreement						
RSE Restricted Lanes Application Provider					Application Usage Agreement														
Enforcement					Information Provision Agreement					Information Provision Agreement									
Transit Fleet Manager																			
Vehicle Restricted Lanes Application Provider	Application Usage Agreement																		
Transit Vehicle Schedule Management Provider																			
Emissions Manager																			
Information Service Povider		Expectation of Information Provision																	
Weather Service Opeator																			
Vehicle Traveler Information Reception Provider	Application Usage Agreement																		
Traveler																			
Vehicle Roadside Information Reception Provider	Application Usage Agreement																		
Parking Manager																			
Other ISP																			
Social Media Provider																			
Media Provider																			
RSE Traveler Information Communications Provider																			
Maint and Constr Manager																			

	Vehicle Owner	Driver	Vehicle OBE Owner	Roadway Owner	RSE Owner	RSE Operator	ITS Roadway Equipment Owner
Vehicle Owner		Vehicle Usage Agreement	Vehicle OBE Usage Agreement				
Driver	Vehicle Usage Agreement		Expectation of Information Provision				
Vehicle OBE Owner	Vehicle OBE Usage Agreement	Expectation of Information Provision				Expectation of Data Provision	
Roadway Owner					Service Delivery Agreement		
RSE Owner				Service Delivery Agreement		Operations Agreement	Information Exchange Agreement
RSE Operator			Expectation of Data Provision		Operations Agreement		
ITS Roadway Equipment Owner					Information Exchange Agreement		

Table 4 ARC-IT Version 8.2 Collaboration Part II

	Traffic Operations Personnel	Vehicle Basic Safety Provider	Vehicle Environmental Monitoring Provider	RSE Traveler Information Communications Provider	RSE Traffic Monitoring Provider	Emissions Manager	Information Service Provider	Weather Service Operator	Traveler	Emergency Manager	Financial Manager	Vehicle Interactive Traveler Information Provider	Vehicle Roadside Information Reception Provider	Parking Manager	Other Information Service Provider	Social Media Provider	Media Provider	RSE Traveler Information Communications Provider
Vehicle Owner		Application Usage Agreement	Application Usage Agreement									Application Usage Agreement	Application Usage Agreement					
Driver							Expectation of Information Provision											
Vehicle OBE Owner									Expectation of Data Provision									
Roadway Owner																		
RSE Owner				Application Usage Agreement	Application Usage Agreement		Information Exchange and Action Agreement											Application Usage Agreement
RSE Operator																		
ITS Roadway Equipment Owner																		
ITS Roadway Operator																		
Transit Vehicle Operator																		
Traffic Manager	Employment Agreement						Information Exchange and Action Agreement											
RSE Restricted Lanes Application Provider																		
Enforcement																		
Transit Fleet Manager							Information Exchange and Action Agreement											
Vehicle Restricted Lanes Application Provider																		
Transit Vehicle Schedule Management Provider																		
Emissions Manager							Information Provision Agreement											
Information Service Povider						Information Provision Agreement		Information Provision Agreement	Expectation of Information Provision	Information Provision Agreement	Information Exchange and Action Agreement			Information Provision Agreement	Information Exchange Agreement	Information Exchange Agreement	Information Provision Agreement	
Weather Service Opeator							Information Exchange and Action Agreement											
Vehicle Traveler Information Reception Provider																		
Traveler							Expectation of Information Provision									Information Exchange Agreement		
Vehicle Roadside Information Reception Provider																		
Parking Manager							Information Provision Agreement											
Other ISP							Information Exchange Agreement											
Social Media Provider							Information Exchange Agreement		Information Exchange Agreement									
Media Provider							Information Exchange Agreement											
RSE Traveler Information Communications Provider																		
Maint and Constr Manager						Information Provision Agreement												

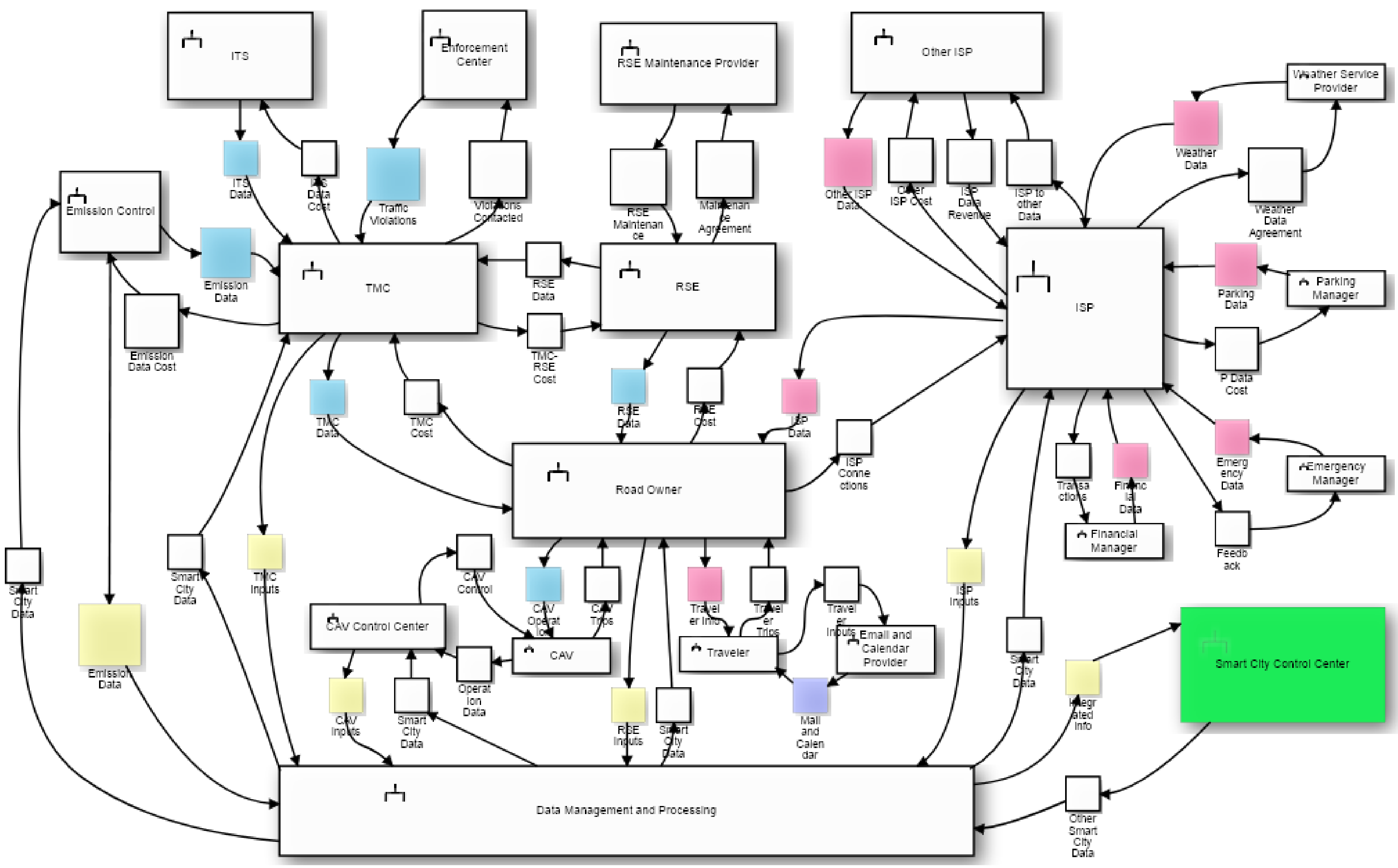


Figure 3 CAV as Part of a Smart City

3.3 Roles in CAV Ecosystem

Figure 4 shows the VDML roles and the provided values for the main players in the CAV ecosystem. The business partners under study in the VDML are those who are directly connected to the business owner. The road owner is the business owner in this case, and the business partners are the TMC, ISP, and RSE provider. Each of them supplies the road owner with a value that is necessary for the road owner to deliver the service to the CAV traveling on the road. The TMC provides all the ITS inputs related to the trip planning and road conditions all over the transportation network. This is mandatory for the CAV to plan the next exit and the most efficient and the safest trip to reach its destinations. The data include traffic updates and emergency updates for all the roads, and weather conditions that affect the trip security and, consequently, the trip planning. The ISP has a lot of data that is usually sent to the passengers of the CAV. It is sent through an agreement with the road owner and therefore the business model shows the data sent to the road owner first and then to the traveler. The RSE provider in this model is the company that provides and operates the DSRC equipment that is essential for maintaining V2I communications. This company will provide the road owner with its services and through that business agreement the CAV will benefit from this value. Finally, the CAV is the customer, and the CAV here represents the driver or the passenger of the

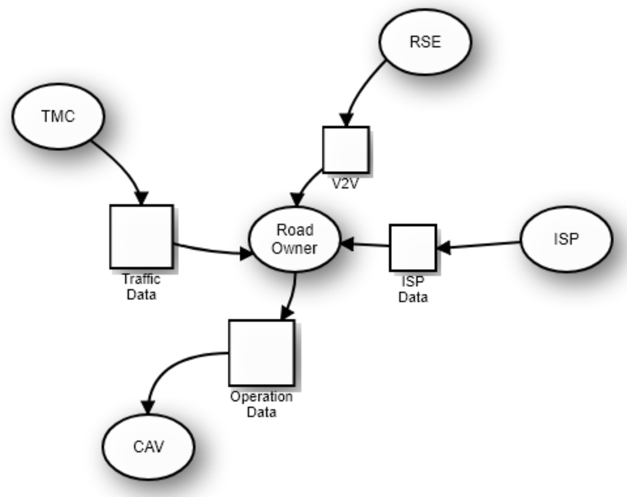


Figure 4 Roles in the CAV ecosystem

CAV. The model is flexible in the sense that if the CAV is anywhere from level 3 automation to level 5, the model will be adequate as the values exchanged in the model remain the same.

Table 6 Roles and exchanges values

Business Entity	**Role**	**Value**	**To**
TMC	Business Partner	Traffic Data	Business Owner
ISP	Business Partner	ISP Data	Business Owner
RSE	Business Partner	RSE Data	Business Owner
Road Owner	Business	CAV operations data	CAV
CAV	Customer	Usage	Business Owner

Table 6 shows the roles of each of the business entities. Because we look at the ecosystem from the road owner perspective, the road owner is defined to be the Business that is under investigation. All the other providers are considered as business partners. Defining the other entities as business partners means that there will be an exchange of values that leads to the delivery of the values to the customer. The customer will get the value of CAV operations data form the road owner and return, the customer will give a value to the road owner, which is the usage of the road. The road usage includes the fees per trip which in turn generate the revenue, and customer satisfaction, which will guarantee business continuity.

3.4 High Level Activities of The Business Entities

Figure 5 shows the business network activity diagram. The diagram illustrates the business partners and the activities they carry to exchange the values and achieve the desired outputs. The horizontal lines represent the different players in the system, and for every player, the respective activities are displayed. The activities are shown as activity boxes, for example, the ISP provides

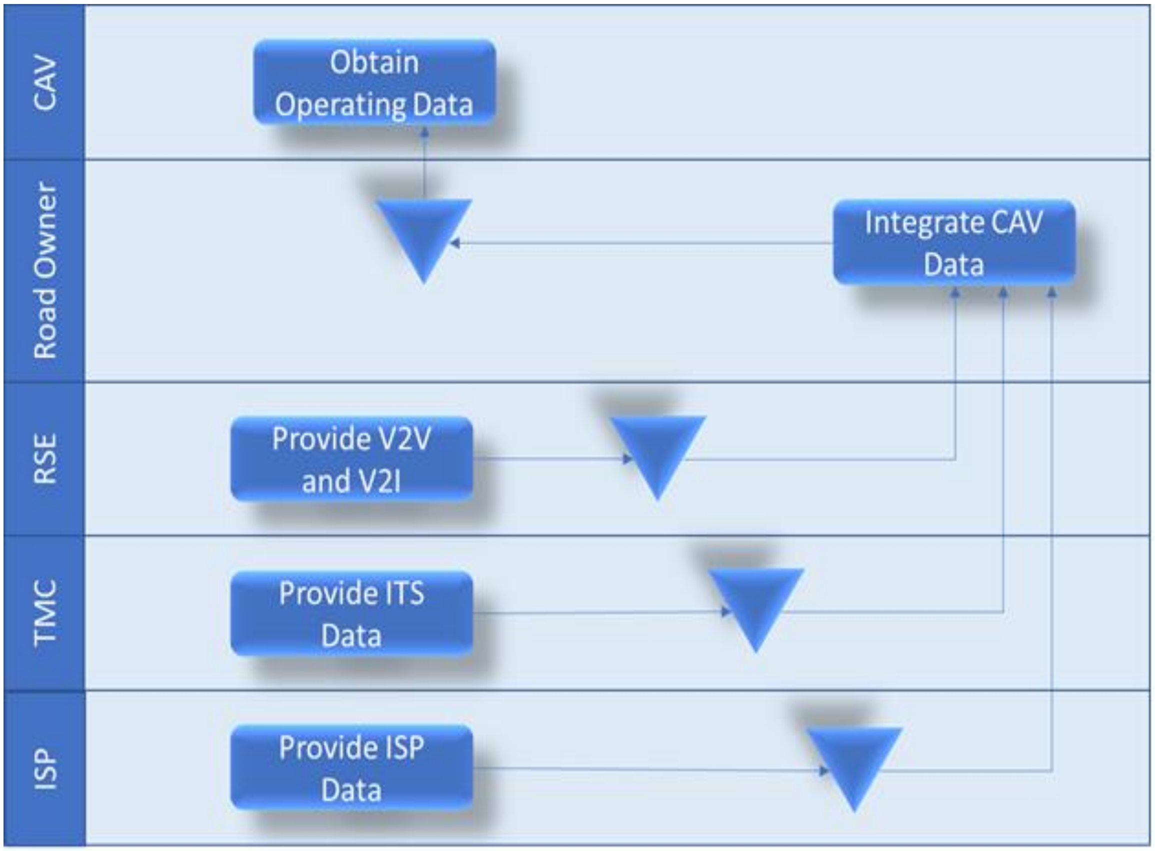


Figure 5 Road Owner Business Network Activity Diagram

ISP data, and this is shown in a box. The triangles mean that the product of the activity can be stored until requested by the receiver, which is exactly the case in CAV. Only when the CAV is using the road, the data will be needed. Some of the activity in the above diagram need to be expanded in other activity diagrams, for instance, if we are studying the business model of the RSE, there will be other activities and exchanged values with other partners to produce the V2V and V2I data through the RSE.

3.5 Capability Management Diagram

Figure 6 shows the capability management diagram that shows how the ITS data is handled to reach the customer. The CAV ecosystem has many capabilities, for each group

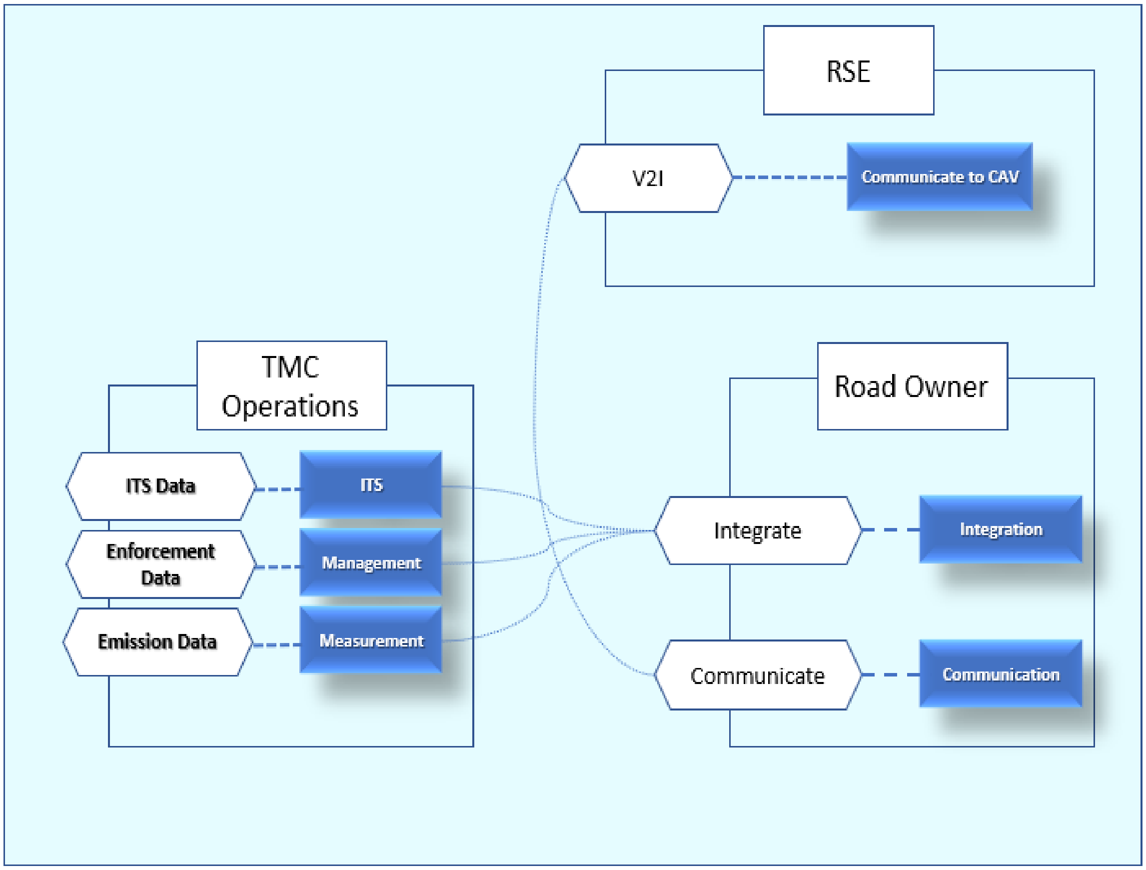


Figure 6 Capability Management Diagram

concerned with certain values to be delivered to the CAV, a separate diagram should be constructed.

The large boxes in the graph represent the organization or a certain unit in an organization and on top of it the name of the organization or the unit is displayed. In other applications, such a graph could represent a community. In our case, the first box in the bottom left side represents the TMC as an organization. The hexagon boxes to the left of the TMC box reflect the capability offers that are provided by the organization. In the figure, the ITS data, Enforcement Data, and the Emission data are the capability offers offered by the TMC. The connected boxes to the right of the capability offers are the capability methods, which are used to provide the capability. The capabilities are then interchanged with other entities or organizations, so the TMC capabilities are exchanged with the Road Owner as a business entity, they are first integrated and then communicated to the CAV through another capability in the RSE.

The connections are physical connections that describe the value stream from the capabilities at each of the business entities. Similar graphs could describe the ISP exchanged values with the road owner and the RSE to finally communicate the values to the CAV. We note that the capability management diagram reflects the capabilities used and their related methods which is a good way to understand the value stream, however, it needs more data and more insights on the values that are exchanged. This will be managed in the VMP tool in chapter 4.

3.6 Value Contribution

To further understand the value streaming and to have a holistic view about the business and its ecosystem, the Measurement Dependency Graph was introduced. The graph shows how the values are exchanged and integrated to reach the final customer. The decision makers can visualize the roles and the contribution of each business partner to the overall purpose of the value deliver to their customers. Figure 7 shows the sources for value contributions for the CAV. the Cav passengers, whether they are travelers or CAV owners, perceive the value received from the experience of traveling on a certain road. These are the factors that affect the satisfaction levels of a CAV passenger traveling the on the road.

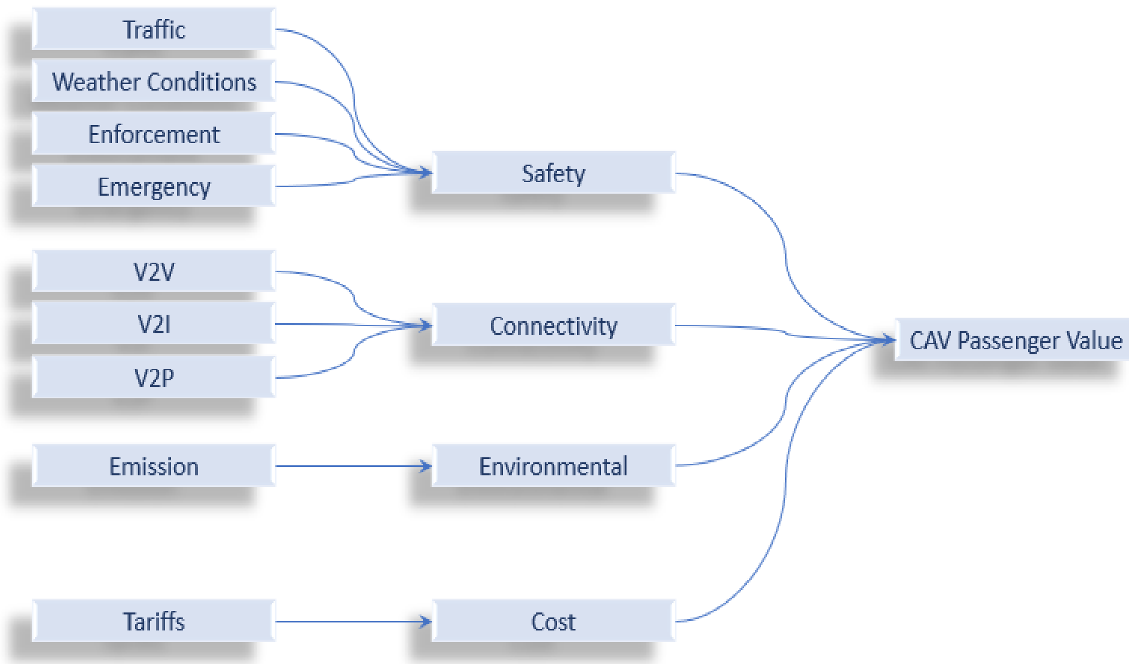


Figure 7 Dependency Graph

The CAV passenger will realize the value based on the values of safety, connectivity, environmental, and cost. The cost of using the road is mainly the tariffs applied by the road owner, which has many values based on various offers. It is a key satisfaction point as the overall value perceived by the CAV passenger must justify the cost of the trip. Currently, the toll roads are used to save time and to add more driving convenience, which will be the case for CAV plus more values to be realized. One of the main values is Safety on the road. The CAV will constantly receive data from ITS about the traffic all over the city which will be used in trip planning, and the weather conditions will affect the driving speed and the driving technique. For a level 5 vehicle, the weather conditions are extremely important as the car will decide on the suitable speed to drive on the road. Also, the emergency data is important as the traveling speed and the trip planning change upon any emergency condition. The CAV will adhere to variable speed limiting and to the dedicated lanes enforcement in case of emergency.

The CAV must maintain connectivity to other CAVs on the road throughV2V communication, which allows the vehicles to determine the distance to surrounding vehicles and learn about their exact locations and speeds. Also, it must maintain vehicle to Infrastructure (V2I) communication at all the time to be able to receive updates about the road conditions, traveling speeds, dedicated lanes and other important data. One of the most important communication streams is the Vehicle to Pedestrian (V2P) which allows the vehicle in urban areas to communicate with pedestrians and know their positions for achieving a safer ride.

3.7 Insights on CAV VDML Modeling

Building a VDML model for the CAV ecosystem from the road owner perspective was not attempted before. The VDML analyst should collect all needed data about the business and build the model with a high level of accuracy. The following are some useful insights on VDML modeling for CAV.

The analysis starts by assessing the As-Is situation. The model should be constructed after considering all the value streams and then it should be verified before adding any To-Be investments to it. In our case, the model will be constructed for the CAV from the perspective of the road owner business.

Value streaming is essential for defining the scope of the business analysis. The value streaming explains the flow of values in the ecosystem and the elements that are connected directly or indirectly to the value propositions. The value stream molds together all the values created and exchanged in the system, activities and capability methods, and the value propositions of the suppliers. For the suppliers to deliver the value propositions, they too might have their own value streams, and those should be included if a full investigation of the business ecosystem is needed.

The importance of an automated tool arises from the fact that building a business model for a single company can be achieved no matter how difficult it is, however, when we consider an ecosystem where many enterprises interact together and exchange variable values, the environment becomes too complex for simple modeling. Therefore, the VDML is extremely important for businesses.

The business scenarios can be defined as the measurements that would lead to different outcomes. This is mandatory when business owners are to investigate various alternatives or investment choices that would lead to different outcomes. The value propositions that emerge from each alternative can be computed and the satisfaction levels for each of them can be defined. VDML can support different measurements of the same model, or different changes of the model itself, for example, to invest in one alternative or another with two different partners that will generate different value propositions.

Iterative refinement of the model is mandatory. While forming the as-is situation, the analysist will construct the ecosystem based on interviews and existing data. In the case of the to-be situation, the researcher will need more flexibility to refine the future situations that do not exist yet.

One of the VDML limitations is that a complete model for a certain ecosystem might take years to be done, and it will still be a moving target as situations change and must be updated. The business model evolution will continue, and the analyst must update the data every time it changes to reflect reliable level of confidence in the model at the decision makers. The analyst will also focus on the model for the business owner and the related business partners, although there might be other companies that interact with the business partners and, in a way, affect the value propositions and the value streams.

VDML will handle the contractor personnel and their capabilities in the same manner it treats internal personnel and internal capabilities. In our case, the RSE personnel and capabilities will be utilized to provide capability offers to the road owner, which is the same as the internal road owner personnel and capabilities are represented in the model. This reflects the flexibility of the tool and this is mainly because it focuses on capabilities and capability offers.

The knowledge discussed in chapter 3 included the ARC-IT Version 8.2 connected vehicles architecture provided by U.S. DOT and that has been used to generate the list of enterprises in the CAV ecosystem and identified the services exchanged amongst those enterprises. The VDML products of the ecosystem were also discussed to show how the VMP modeling in chapter 4 will add great value to the business modeling and will have more insights that will assist the decision makers in their tasks.

Chapter 4

The VMP model was constructed to assist the road owner on future business decisions. The model is based on the architecture of ARC-IT Version 8.2 issued by U.S. Dot. The road owner can have better business insights and more efficient risk identification based on deep understanding of the value creation and value exchange with business partners and customers. The model considered the customer satisfaction based on NPS and it was considered in forecasting of the business results. The investment or outsourcing of the RSE function is investigated to give the decision makers the ability to make sound decisions.

4.1 VMP Model for CAV

4.1.1 Assumptions

Further to the assumptions mentioned in section 1.4, other assumptions need to be highlighted. The basic activity to build the VMP model is to have business interviews with business decision makers and their experts to be able to determine the accurate forecast and the actual monetary values that will be used in the model. In our case, the CAV industry is a thing of the future, no one exactly knows how much the cost will be. The VMP model will facilitate the future updates of the actual values, as the model will be built based on the business relationships. The forecasted number of trips by CAV on the road was projected at 10% of current trips made on ETR407.

The ETR 407 team was contacted and they reported that they expect CAV trips to be around 300,000 trips in the first year. They have an annual agreement with TMC, and it was assumed that 10% of that will be invested for the CAV operations. The 407 ETR revenues are reported in [2], and out of this the forecast and revenue of the CAV was deduced.

4.1.2 VMP Plan for CAV

The VMP tool was used to create the model for the CAV ecosystem. Figure 8 shows the plan creation in the VMP. The “As Is” situation is in the first phase, and the “To Be’ situations are shown in Years 1, 2, and 3.

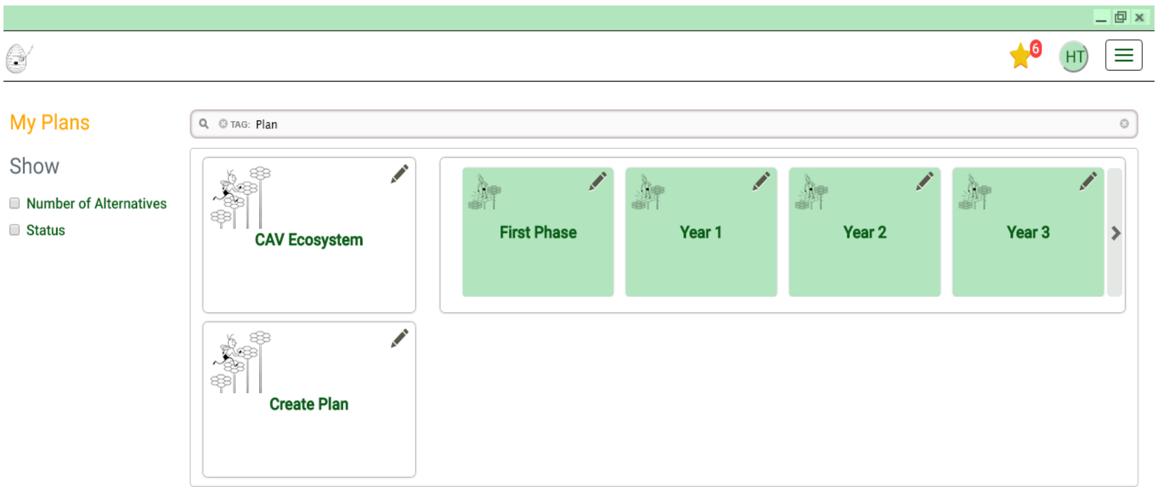


Figure 8 CAV Plan Creation in VMP

The model was constructed to focus on the Road Owner and the RSE Provider, and the main services needed to operate the CAV. The idea was to build the base model and then define business alternatives and their projections to assist decision makers in those companies to take sound decisions into defining where their companies’ investments should be directed. As mentioned earlier, the VMP tool was used to construct the model. The services in focus are Variable Speed, Dedicated Lanes, Emission Control, and Traveler Information. The reason those services were selected is that these are the main services provided by the Road Owner to CAV traveling on the road. All business entities involved in the creation and delivery of those services were considered. To transfer from the ARC-IT Version 8.2 viewpoint to VDML, careful consideration was needed as instead of thinking of connections between companies, we are considering the services that are provided and the values that are inherent in them. We are also considering the flow of the values.

4.1.3 As-Is Analysis and Model Validation

The start of the VMP analysis is always to assess the As-Is situation. Figure 9 shows the As-Is ecosystem for the road owner and the main business partners. The road owner has an annual agreement with TMC to provide all the transportation data to its customers. One of the main features of 407 ETR is the ease of billing. Cameras detect the license plates of the vehicle and the value is billed automatically. Another alternative is for the subscribed travelers to purchase a device that communicates with road equipment and the trip is then calculated.

The main service of 407ETR is the reduction in trip time. The satisfaction of the customers is resulting from the values they perceive on the road usage. The model considers the value exchange between all business partners and the values perceived by the road users. Safety is one of the main values that road users seek when they drive on any road. Also, the main feature for the customers to use the road is to save time and avoid congestion. The road quality and traveling at regular speeds mean that the vehicle will be maintained in good condition while using the road, which means more customer satisfaction. Finally, the customer experience regarding the toll calculation, call center, and online experience adds a lot to the overall value recognition by the customers.

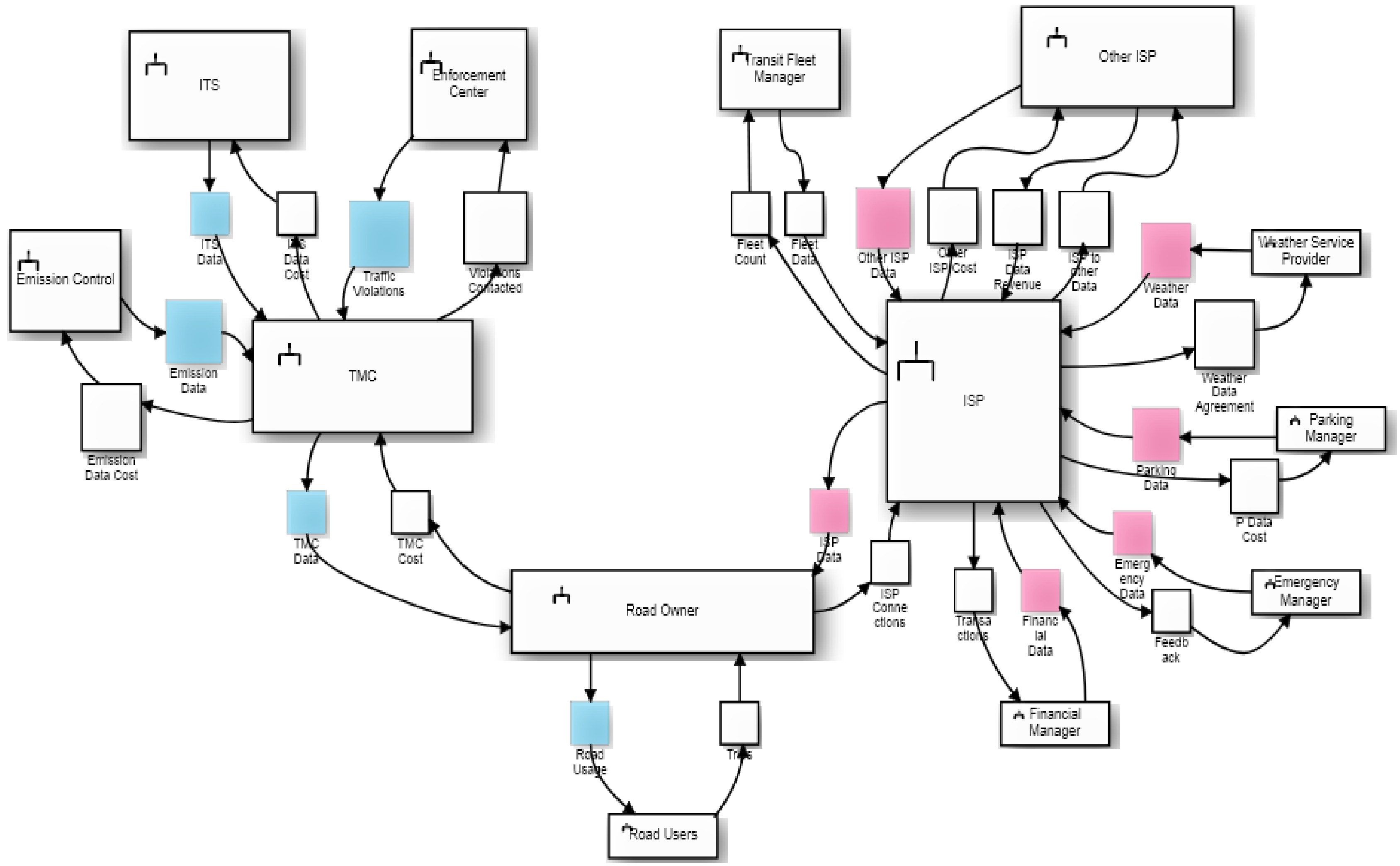


Figure 9 407 ETR As-Is Analysis

The NPS score, mentioned in section 2.2, states that the customers can be promoters, passive, or detractors. The promoters are the ones who promote the value to people they know, so it is an important goal for any business to have his customer satisfaction figures above 80% to be in the promoters' region.

Financial data of road owner business 407ETR [28] was used from 2013 as the "As-Is" scenario, and the model projection was done until 2016 as the "To-Be" scenarios. In the model, the 2013 data is used as first phase, while 2014, 2015, and 2016 are represented as Year 1, Year 2, and Year 3. The revenue made largely depends on the customer satisfaction. Each year, the model is updated for one of the three NPS categories; promoter, passive, and detractor. For each year, the customers could be promoters, which will increase the business in the following year. Passive customers will not affect the business, while detractors will cause the business to drop on revenues on following years.

Figure 10 shows the model results in case if average NPS score was promoter. The average increase per year was set to 10%. The initial assumption for a Passive NPS was assumed to be 5% and the detractor score was assumed to reduce the revenue by 5%. Then these assumptions were tested against the real data from 2013 to 2016.

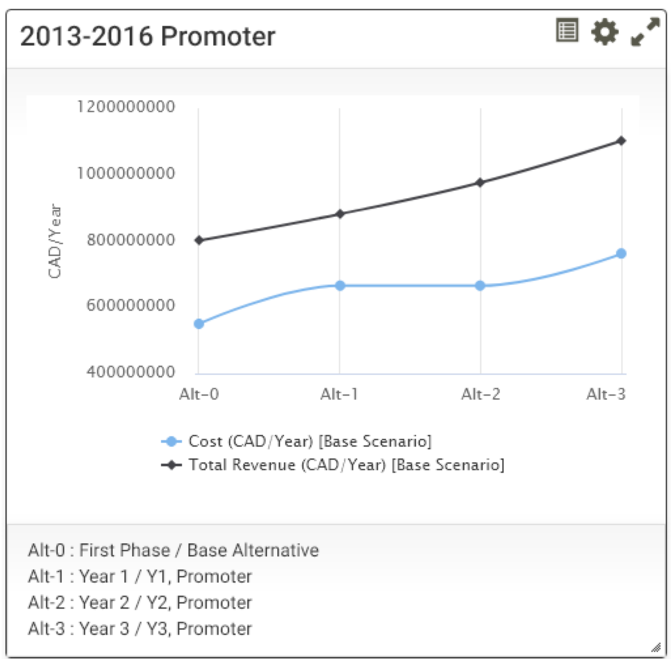


Figure 10 Road Owner Model, 2013-2016

Moreover, it is practical to adjust the model results at the end of each fiscal year, which means that the final adjusted model will be adjusted for 2018 and 2019 as the actual business results.

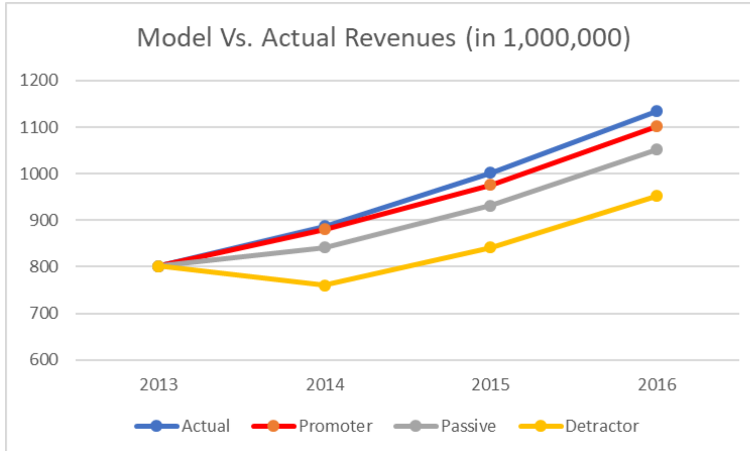


Figure 11 Road Owner Model Vs. Actual Data

Figure 11 shows the model results for Promoter, Passive, and detractor customers. The graph shows that the promoter curve is the most curve that resembles the actual data published by 407 ETR for the same years, consequently, it is fair to assume that the customers of 407 ETR will follow the promoters' curve for next years' performance.

The assumption from the 2013-2016 study for the model revealed that the 10% business increase assumption for the promoter was the closest to the actual figures with 98% accuracy.

To enhance the model accuracy, the model was retested from 2014 to 2017 with the assumption that the promoters will increase the year over year revenue by 12% instead of 10% to reach a very close value to the realistic data.

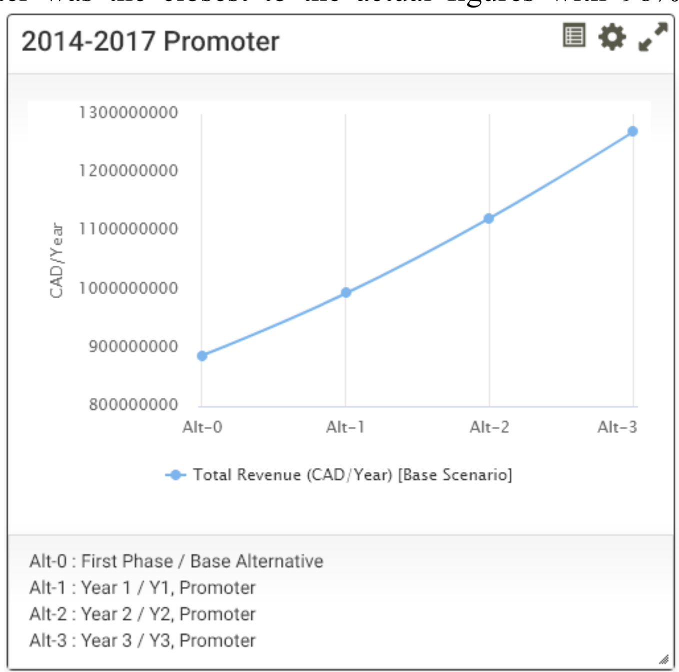


Figure 12 Road Owner, Promoter, 2014-2017

Figure 12 shows the model projections of the revenues for the road owner, for road 407ETR, from 2014 to 2017 for the promoters. Comparing this result to the actual data from the company's records will reveal that the accuracy level has increased to 99.5% provided that the promoters will increase the annual revenues by 12%. The comparison is shown in figure 13.

The actual curve is shown in blue dotted line and the model forecasted curve is shown in red color. The 407 ETR is an award-winning provider in terms of customer service and customer satisfaction, therefore, these results are aligned with actual business figures.

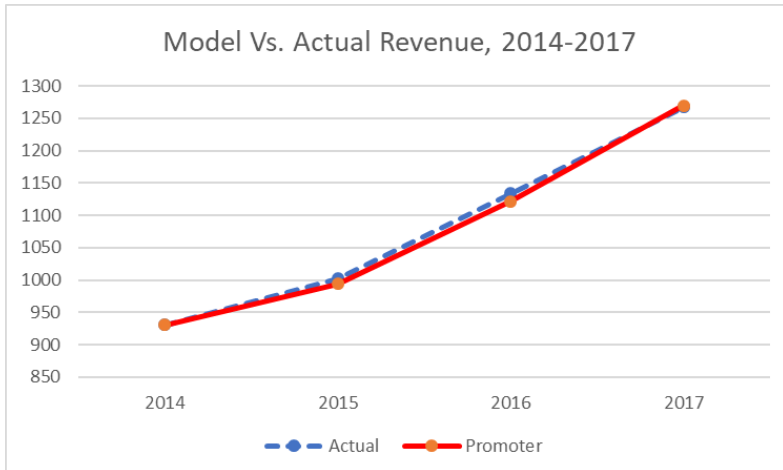


Figure 13 Model Vs. Actual Revenue, 2014-2017

4.1.4 CAV ecosystem, To-Be Analysis

Figure 14 shows the ecosystem built using the VMP. The Road Owner will be the only point of billing for the CAV road users; therefore, all other business entities provide their inputs to the road owner and the road owner forwards those inputs to the CAV and the travelers. This's based on an assumption that in this model, the customers will pay the Road Owner for the integrated service packages, while the road owner will have agreements with all other entities that provide their services. It is important to understand that the relationship in VDML is a value delivery relationship and not necessarily a direct connection as was the case in ARC-IT Version 8.2. For instance, if a traveler is using the CAV on the road, he will receive the traveler's info through his mobile phone from his ISP provider, or through the ISP from the Social Media Provider, however, in the VDML, as explained, as the Road Owner will have business agreements with all entities, the Road Owner will provide this service as part of the package of services delivered to the CAV and the traveler.

Traffic Management Center (TMC), and the Road Owner. The Road owner can benefit from this data to know how much emissions exist on the road and can pass this data to CAV as well. Emission monitoring is essential for environmental reasons. It is a general perception that CAV will be all electrical, while in fact, CAV technology can be applied also to hybrids and to fossil fuel cars as well.

The ITS is responsible for integrating all data received from all possible roads to make the trip safer and more efficient. One valid note is that the ITS could be a part of the TMC, however, we show it here as a separate entity as it could be a third party from the TMC perspective. The ITS data is collected from many sources, such as cameras on the road and in vehicles, vehicle locations, and other data sources. The ITS integrates and processes the data collected to give information to other entities such as the TMC and the RSE Provider. The values exchange between ITS and TMC is shown. ITS gives three services, or values, to the TMC; ITS Traffic, ITS Basic Surveillance, and ITS Variable Speed Limiting; while it receives, as a value exchange, the same information form the TMC perspective, namely: TMC Traffic, TMC basic Surveillance, and TMC Variable Speed Limiting. The ITS also provides the RSE Provider with ITS traffic, ITS basic Surveillance, and ITS Dynamic Lane Management information.

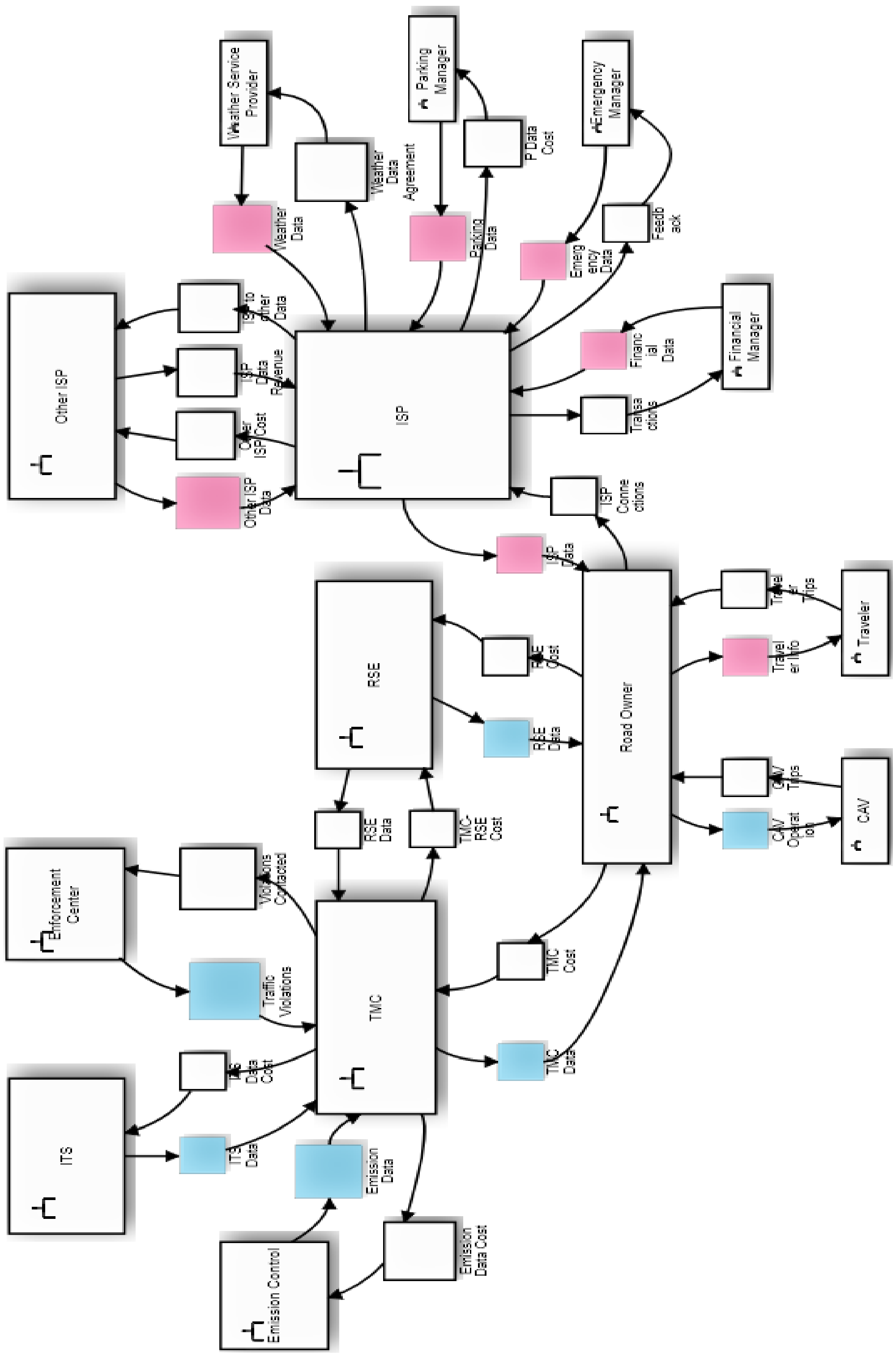


Figure 14 CAV Main Model

The first entity that is delivering value to the CAV is the Emission Manager. The emission manager is responsible for monitoring emissions and in some cases, react to them. The Emission Manager passes the emission data to Intelligent Transportation System (ITS), The TMC interacts with many entities in the ecosystem. As we explained its relationship with ITS and Emission Manager, we can also note the information exchange between the TMC and the RSE provider. The TMC provides the RSE provider with TMC Traffic, TMC surveillance, and TMC variable speed. And it also provides the same services or information to the road owner.

In the heart of the system, we find the RSE provider. In figure 14, the RSE Provider and the Road Owner are two separate entities, later we will present the model where the Road Owner owns and operates the RSE. The RSE Provider owns the RSE and operates it or agree on its operation. Usually, the provider will sign an operation and maintenance contract with the owner, in our model we assume that the RSE Provider is a single entity that provides, operates and maintains the RSE. The RSE provider receives the TMC information and process it along with its own data. RSE also receives ITS basic surveillance and ITS traffic, which are similar to the ones provided by ITS to the TMC, and also receives ITS Roads Operation and Maintenance information. The ITS information package is integrated with the TMC one and the data is processed to provide accurate information to the CAV. Another entity that integrates with RSE Provider is the Internet Service Provider (ISP), and in this case, both entities are concerned with Traveler info. The RSE Provider provides the Traveler information concerned with the CAV on the road, as it exchanges its data constantly with RSE. On the other hand, the ISP provides the RSE with travelers' data which include the weather conditions, the parking info and other important data for the operation of the CAV. Finally, the RSE communicates all the integrated and processed data, along with its own operational data, to the CAV. Although the physical connection is directly from the RSE to the CAV, the model shows the business flow or the value stream, where the service is provided to the end user through business agreements with Road Owner.

The ISP integrates all the data received from different entities, including other ISP providers and passes the final information to the traveler, again through an agreement with the road owner. The ISP receives data from weather service operator, processes it to integrate with data from other ISP providers, and includes it in its package sent to the RSE or to the CAV/Traveler. The ISP also receives data from the parking manager, which facilitates the parking services for the CAV, and is extremely important. The CAV needs this data to decide on the destination parking area and consequently, decide on which exits to use from the road it travels. One of the most important inputs to the CAV operations is the Emergency Manger input, which is reported through other entities such as the ITS and the TMC.However, more sources of data is better for ensuring the security and safety of the CAV and its passengers. The ISP receives this data form the emergency manager and includes it in the traveler info data passed to the traveler, and to the RSE Provider as well. In case of any emergency, the CAV can decide to avoid the emergency areas, or decide on stopping the trip and parking in a safe area if it is a major emergency. Finally, the financial manager is concerned about the toll of the road or any other fees that are necessary to be paid, it could be government operational fees as well. All this data is integrated by the ISP and passed to other ISPs, RSE, and the traveler, which could be the car owner as well.

The business model ecosystem helps the road owner in decision making process. It helps the business owner to *realize the opportunity* in CAV readiness, visualize how *the alternative* of outsourcing the RSE investment would be and how would it affect the value creation, and finally, *evaluate the alternative* and study its impact on revenue from a value-based perspective. Another benefit of the business model ecosystem is that the knowledge provided helps the road owner to *identify* potential risks in value creation, *validate* them, and choose appropriate risk management strategies.

4.1.5 Business Model Service Cube

Figure 15 shows the road owner business model service cube. The six sides of the cube represent the Value Propositions, Network Partners, Customers, Activities, Competencies, Values, and Customers. As this model is built for the road owner, the Value Propositions show the services that are exchanged in the ecosystem. These propositions are offered either from the road owner to the customers and partners, or propositions offered by partners to the road owner. Those propositions are the basis for value exchange. For instance, the ISP Data is received by the CAV and the Traveler through agreement with the road owner, consequently, the value flow is from the ISP to the road owner and then to the customers. Another Value proposition is the CAV operations, and it is a pack of data that is integrated by the road owner through the Data Center and the Employees, and then pushed to the CAV. The CAV Operation is a value that is represented by a package which includes all the data receive by the road owner form the ISP, TMC, and RSE; and then delivered to the CAV and the Traveler.

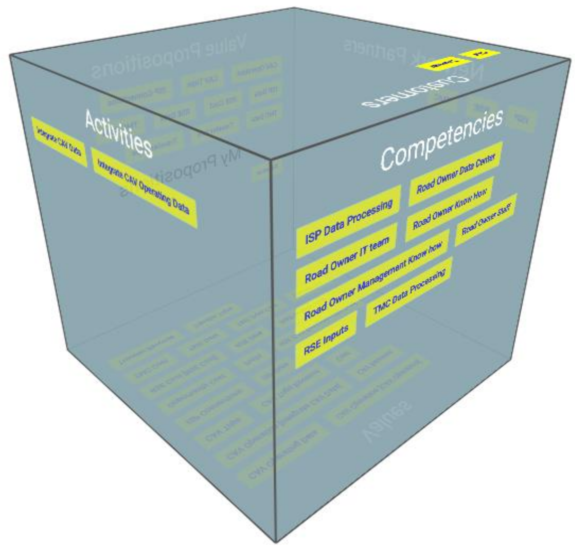


Figure 15 Road Owner Service Cube

The cube also shows the Network Partners, which are the TMC, ISP and RSE. Those are the main business partners who have a direct connection with the Road Owner, and therefore they are considered in this business model. For other business models, the ISP business model for example, the business partners will be a totally different group as they will be the companies or entities that have direct connection with the ISP, and therefore the TMC will not be part of that business model.

The Cube also represents the competencies used by the business in interest to create the values delivered to the customer. On the competencies side, we find two types of competencies; Resources and Capabilities. The Road Owner Data Center is a resource, but the know-how of the personnel operating the data center is a capability. The importance of including the competencies is to show which business areas are incorporated into the value creation.

The cube Activities show the main activities that are carried out by the business, which is the road owner in this case, to deliver the needed values to the customers. The road owner will integrate the data received by the various sources to produce CAV Operating Data and Traveler Data. The CAV operating info include many inputs, and the TMC has an annual deal to provide the road owner with the TMC data. The TMC integrates and processes the inputs from ITS, RSE, Emission Control and Enforcement center, which are necessary data to know the road conditions, plan the trip further beyond the current road, and define the trip parameters for the CAV. One of the most important inputs that are included in the TMC data package is if there are dedicated lanes for the CAV operations.

When the business decision makers *define* their main competencies and their *contribution to value creation*, they will reach a sound decision about where to direct their investments to acquire or enhance those competencies. The business cube view adds a new perspective for the business owner in risk identification as it clearly states the activities, competencies, and values exchanged in the ecosystem.

4.1.6 Business Strategy Map

Another product of the VMP is the business strategy map. As figure 16 illustrates, a business strategy map details the value streaming through the ecosystem. For the road owner, certain competencies are needed to integrate the data received from other players and deliver it to the CAV. The Road Owner will use his data center and the staff as resources, and the know-how, to integrate the inputs received from the RSE, TMC, and ISP. The Value Stream lane is where all the allocated costs are displayed, these are the cost incorporated

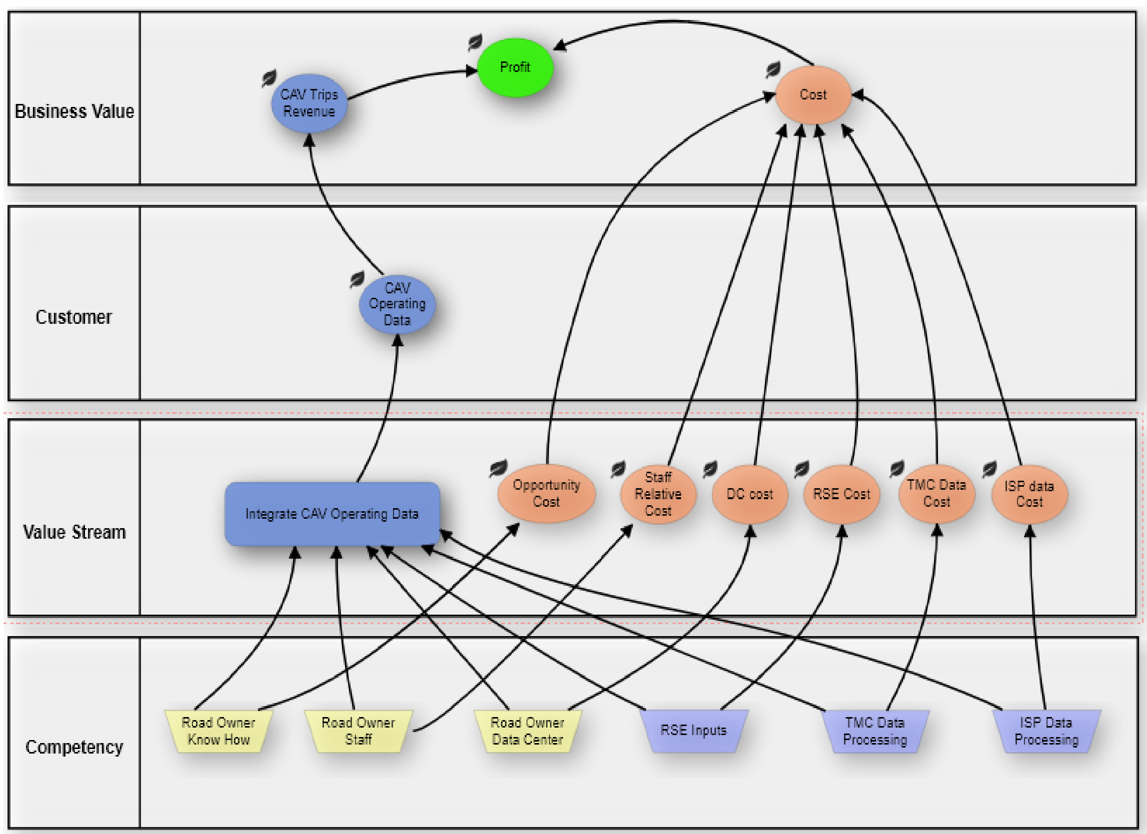


Figure 16 Road Owner Business Strategy Map

in the value creation process. The Business Value lane shows the profit of the business owner, the integrated cost and the revenue are displayed to calculate the profit. The Customer receives the CAV operating Data as a value and provides the Road Owner with the revenue. The figure sheds light on the value flow and how the internal value, or profit, is created, which in turn helps decision makers to visualize the needed competencies and use that in *alternative evaluation*, hence, take informed decisions. The business strategy map can be used as basis for realizing financial risk streams, and the business owner can then assess those risks through deeper investigations.

4.1.7 Value Stream Mapping

Another product of the VMP is the value stream mapping. The services provided in the CAV operations package include Variable Speed, Dedicated Lanes, Traveler Info, and Emission Data. The value stream mapping shows how each of these services is integrated and which business players are involved, and which competencies are used to deliver the service.

Figure 17 shows the Value Stream Mapping (VSM) for the Variable Speed. The variable speed is a major service to avoid congestions on the road or to avoid congestions due to accidents.

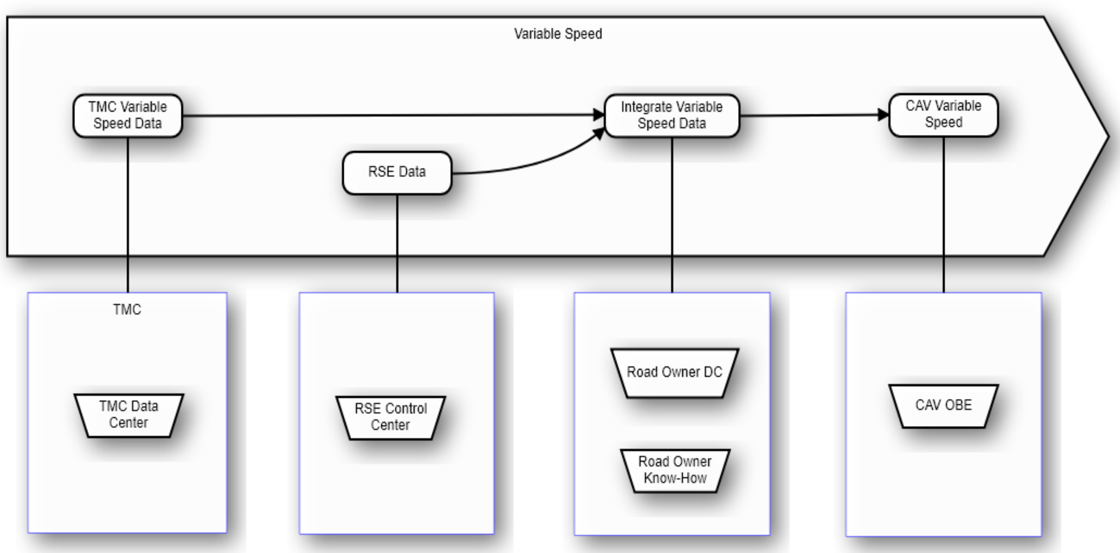


Figure 17 Value Stream Mapping for Variable Speed

The large box on the top represents the service to be delivered, and the name of the service is printed. Each of the rectangular shapes inside the service represent an activity and each activity is carried out by a player in the ecosystem, a player could be the business, business partners, or the customer. Each activity is connected to an external rectangle below the shape, this rectangle is called the Competency Container. Inside the competency container, the respective competencies used by each player are displayed.

The TMC integrates a lot of inputs form ITS and form TMC surveillance and sends them to the road owner. The RSE will provide the road owner with the location and speed of all CAV on the road, or in a wider concept, all the connected vehicles on the road. The road owner uses his data center resources and the capability of the road owner staff know-how to integrate and send the integrated data back to the CAV through the V2I communications. Finally, the CAV uses its On-Board Equipment (OBE) to use the data and apply the speed changes if any. This will result in the CAV proper trip planning on the road as congestions down the road can be avoided by reducing the speed early enough.

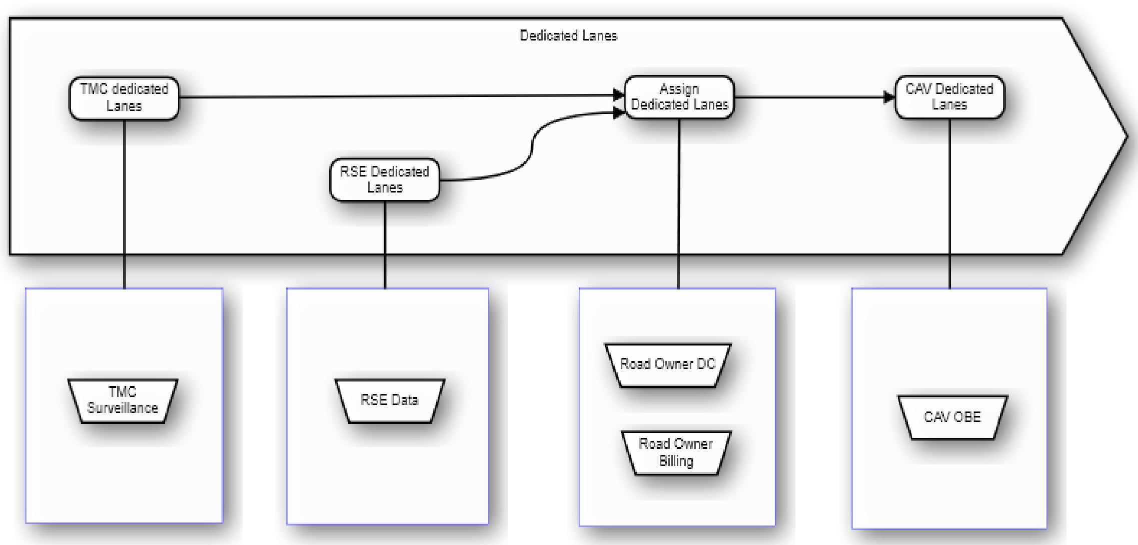


Figure 18 Dedicated Lane Value Stream Mapping

Figure 18 shows the value stream mapping for the dedicated lanes service. The dedicated lane is used in emergencies for emergency vehicle preemption, or, which will be our case, for CAV to drive on the same lane which will be dedicated for them. It is imperative in both scenarios that the CAV be informed of which lane should it drive. The TMC supplies dedicated lanes data to the road owner, and the RSE also supplies the lanes data to the road owner as well. The road owner integrates the data and sends it to the CAV, consequently, the CAV will drive on the assigned lane.

The value stream mapping for Emissions Data is shown in Figure 19. The activities carried out by each business partner are also shown. The road owner's understanding of the value streams will provide deeper understating of how the value is created and transferred and this will allow the business owner to properly define the risks involved in value creation for each of the services offered.

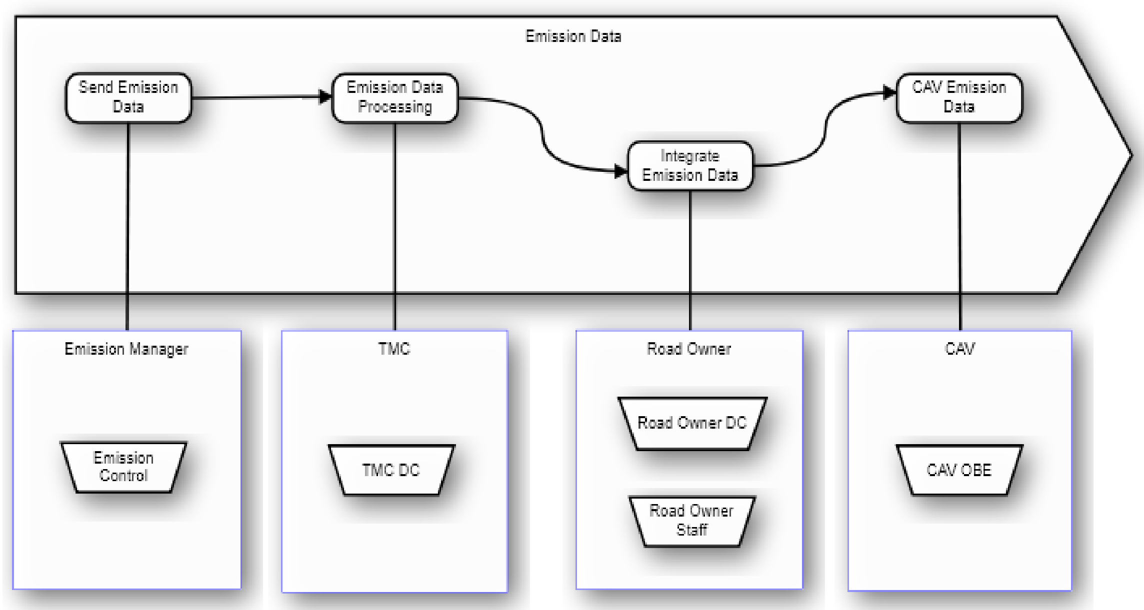


Figure 19 Emission Data Value Stream Mapping

Another example of an important service is shown in Figure 20. The traveler data is an important service as it keeps the traveler up to date with all data that govern the

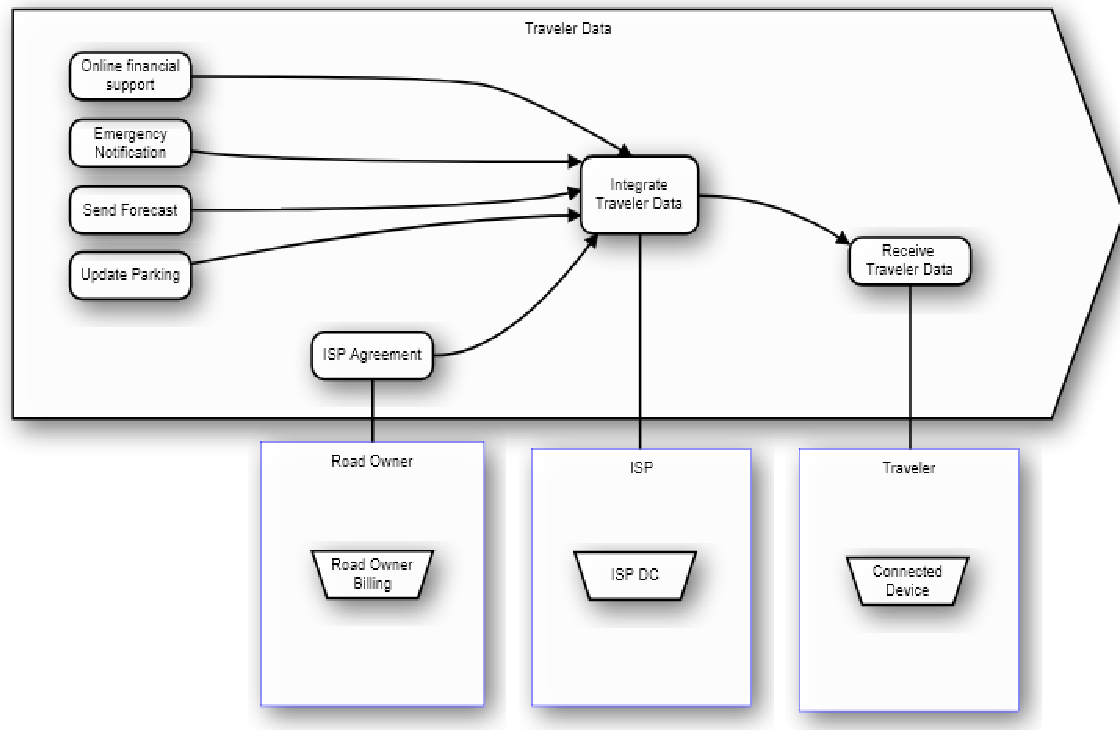


Figure 20 Value stream mapping for Traveler Data

security of the trip and the trip planning as well. As mentioned earlier, the traveler receives the data from the ISP provider through an agreement with the Road Owner. The ISP will integrate the needed data to be sent to the traveler from the ISP business partners. The Parking manager is an entity that is responsible for parking data, such as the available spots and how much it would cost to part there. Considering the CAV, it is logical for level 5 vehicles that the CAV owner or traveler will arrive at his destination and then ask the CAV to park somewhere and then pick him up again. Therefore, parking data is important, and the anticipation is that mobile applications for CAV parking will evolve and they might be integrated with CAV mobile applications. Another important service is the weather forecast, which is also an important service that affect the trip planning and the safe operation of the

CAV. The online financial support is important as this is how the customer will do the billing for the CAV services. Finally, the emergency manager sends emergency notifications to the traveler and the CAV as well to make sure that the CAV will avoid emergency areas and plan a safe trip. All the data is integrated and sent after approval from the road owner as per the agreement.

The value stream mapping is also a very important product of the VMP when it comes to business decisions. This is the part where the road owner can see how the services are created, which business partners take part in it, and which competencies are used. This is very beneficial in *alternative formulation* and *alternative evaluation* steps of decision-making process. Moreover, the risks involved in using those competencies and value streams can be accounted for and further studies by the business owner.

4.1.8 Aggregated Revenue Streams

The aggregated view of revenue streams for the road owner is shown in Figure 21.

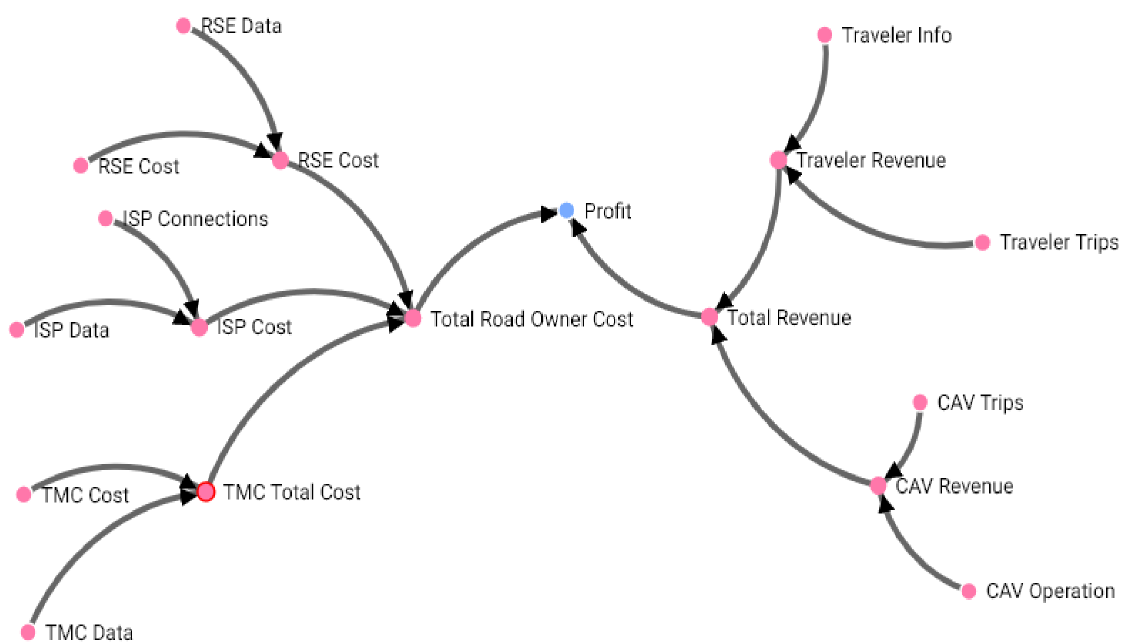


Figure 21 Aggregated Revenue Streams for Road Owner

The main revenue streams for the CAV business are generated by CAV trips and Traveler

Trips. The cost streams are formed by the cost of RSE, TMC, and ISP. The shape is produced by the VMP tool to illustrate the revenue and cost streams for the decision makers of the business. The aggregated revenue streams can be combined with the business strategy mapping to have a complete view about the profit streams and enrich the *alternative evaluation* part of the decision-making process. The aggregated revenue streams can also be used in the identification of possible financial risks.

4.1.9 Business Dashboard

The projections for the basic alternative (Road Owner and RSE provider are two separate entities) are shown in figure 22, the road owner will achieve higher revenues than the costs incorporated. This is assuming that the TMC cost is fixed over the course of the investment and that the forecasted number of the CAV trips per year will increase based on customer satisfaction and based on the model validation done on previous years. Other graphs could be produced so that the business owners can easily take the decisions on the future investment. The tool can produce cost curves that show the cost breakdown and revenue curves that show the revenue streams. Combining this with the Business Strategy Map curve allows the decision makers to make sound decisions.

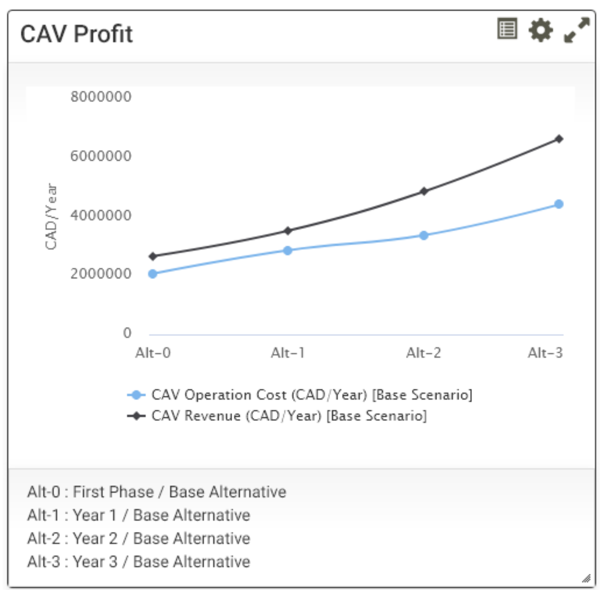


Figure 22 Road Owner Revenue Vs. Cost, First Alternative

Figure 23 shows the road owner revenue streams. The revenue comes from CAV trips, and also from Traveler trips. The travelers are the passengers of CAV who will decide to pay for the trip. The revenue is projected from the first year of operation to the fourth year. The business decision makers rely heavily on such projections in deciding on future investments and they challenge them to make sure that the data is accurate. With the VMP-based projections, the confidence level of deciosn makers will be very high.

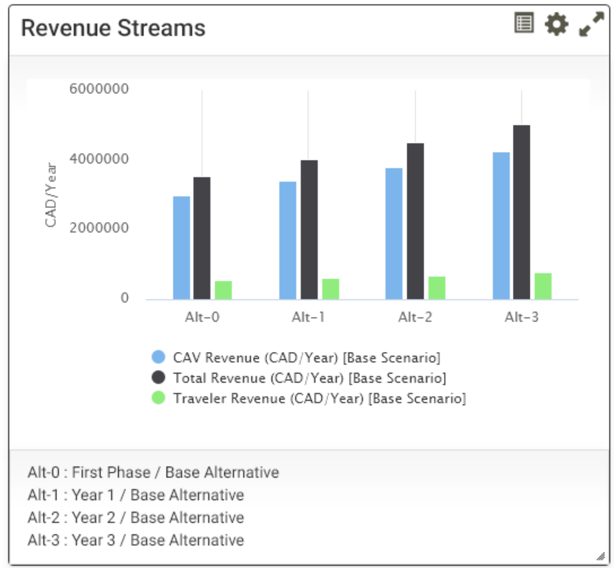


Figure 23 Road Owner Revenue Streams

The dashboard also shows the detailed cost structure of the CAV operations in Figure 24. The road owner can compare his cost structure with the value streams and the ecosystem to get better understanding of how much cost is invested to deliver the required services to the CAV. As the model is constructed over four years, the cost is also presented over the same period as the revenue.

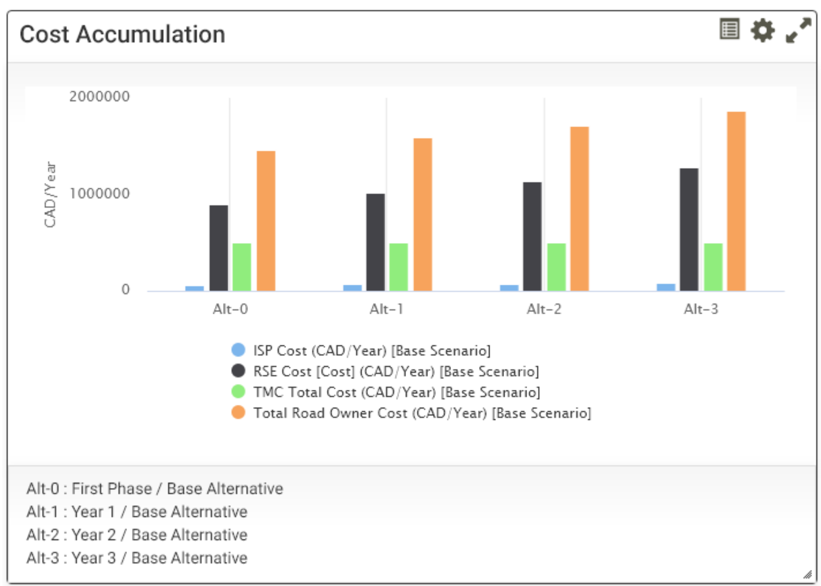


Figure 24 Road Owner Cost Structure

The model can provide moe winsights that would assist the decision makers. Figure 25 shows the Revenue, Cost, and Profit projections. While Figure 26 gives the decision makers the opportunity to compare the cost and revenue in a different manner.

Figure 26 Cost, Revenue, and Profit

Figure 25 Cost and Revenue Comparison

4.1.10 RSE and ISP Business Cube

The business model can be used to view any of the players as a business owner, consequently, the other players in direct contact with the business owner will become Network Partners. Figure 27 shows the service cube from the RSE provider perspective. This is how the RSE views the business as a business owner, and in this case, the Road Owner, TCM, and ISP will be shown as network partners. Once the

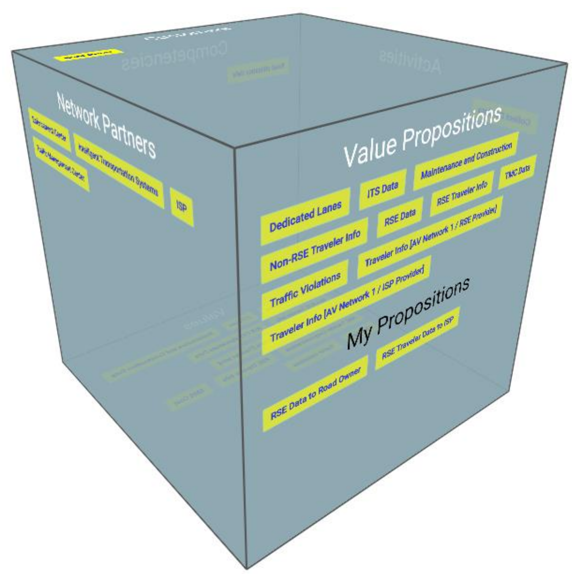


Figure 27 RSE Company Service Cube

cube is built and the value exchanges are defined, the VMP can be used in a similar manner to analyze the business projections.

In a similar manner, the Service Cube for the ISP is shown in Figure 28. In this case, other partners will be displayed as the ISP is interacting with different players than the Road Owner and the RSE provider. For example, The Parking Manager is one the players that communicate with the ISP. Also, the TMC is not interacting directly with the ISP, and thus, it is not in the ISP network partners.

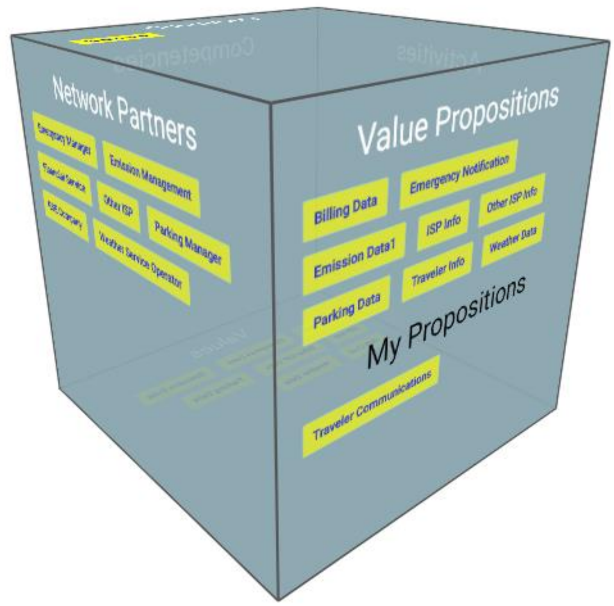


Figure 28 ISP Service Cube

All other subsequent graphs and projections can also be easily generated for each player.

4.1.11 BPMN

Business Process Model and Notation (BPMN) is one of the products of VMP that describes the process view of the ecosystem. By describing the business process value chain through PBMN, the Key Performance Indicators (KPI) of the system can be defined and then monitored to measure the system performance. This will allow business owners to have periodic monitoring of the system performance which will in turn allow for better risk management. Figure 29 shows the BPMN for the CAV ecosystem. It shows the process between the business, partners, and customers.

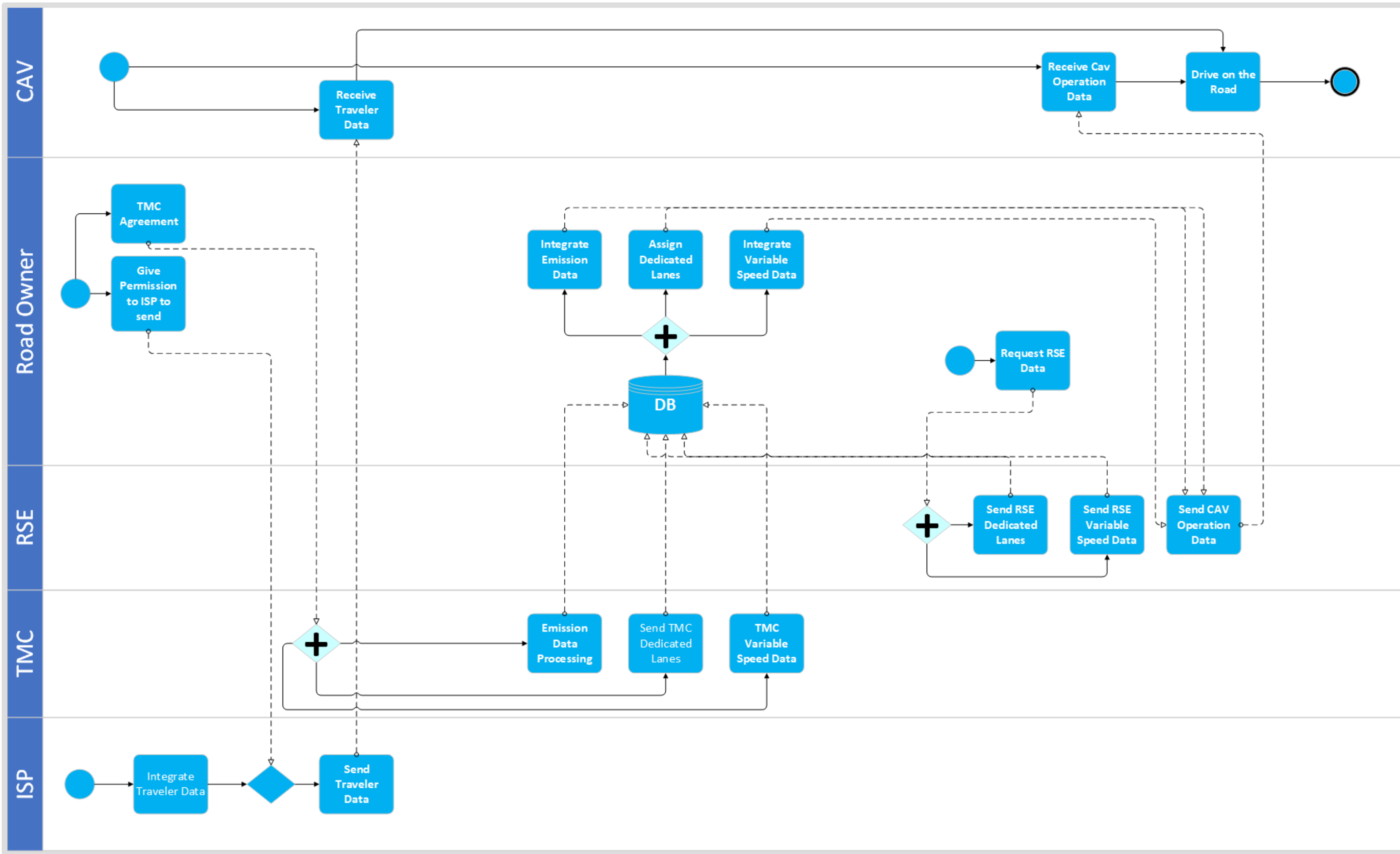


Figure 29 Road Owner BPMN

4.1.12 Business Alternative

The business alternative to be investigated is for the road owner to invest in RSE equipment. The RSE equipment will be added to the first year as capital expanses and the model was built to investigate the profit and loss of the business case. Also, in the BSM, the RSE will be changed from a cost to a competency owner by the business owner.

The model ecosystem map is shown in figure 30. The RSE no longer exists as a

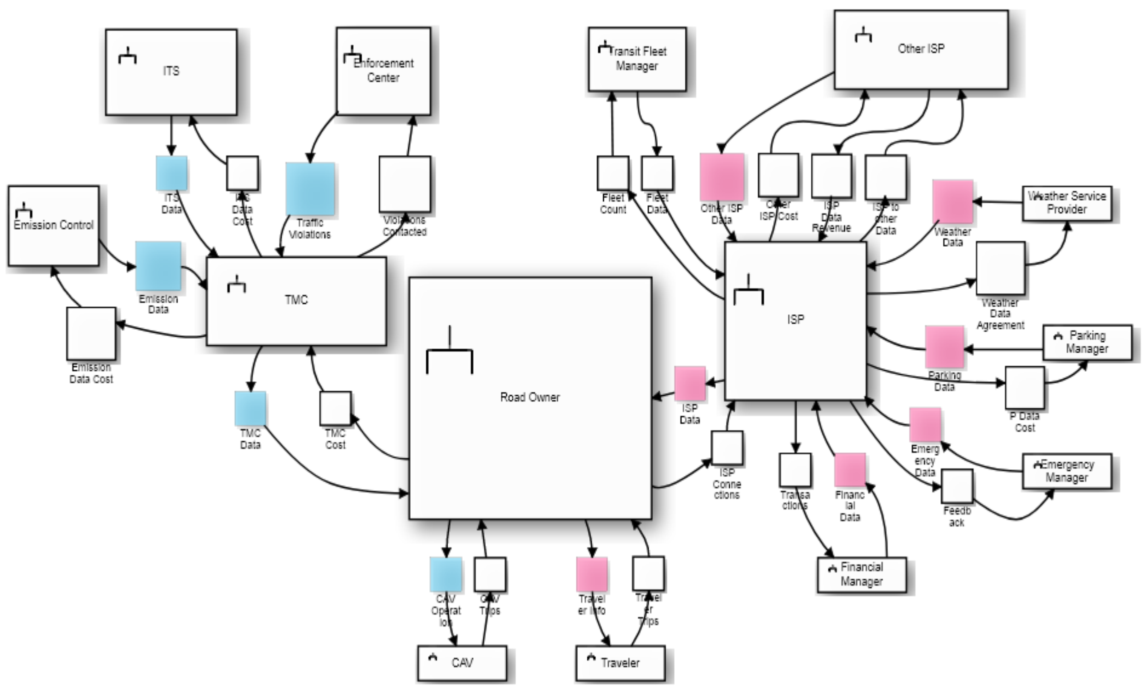


Figure 30 Road Owner Alternative Model Ecosystem Map

provider, because the Road Owner owns the RSE equipment. The US Department of Transportation estimated the operating cost per RSE DSRC station to be between $1,950 to $3,050 a year [29]. This cost will cover maintenance

Table 7 [29] RSE Cost

Cost Element	Per Device Cost per Year
Power	$100
Traditional Maintenance	$500
License/Maintenance Agreements	$200
SCMS Certificate License	$50
Annualized Replacement Cost (every five to ten years)	$1100 -$2200
Total	$1950 -$3050

and replacement of faulty devices if necessary. Table 7 [29] shows the RSE cost breakdown. The table shows that the operation cost without replacement is $850 and that replacement cost is every 5 years. This means that we will consider the construction cost at the first year, and as the model is projected for 4 years, only the operation cost will be considered along with depreciation cost for the replacement.

The 407 ETR length is 138.7 Km. The RSE stations are placed at one Km apart. Many research projects have been conducted to determine the optimum separation distance for the RSE equipment to insure the reliable and efficient operation of the CAV. DSRC equipment support V2V communications which are essential for the safe operations of the CAV. The safe operating distance between the RSE station is at a maximum of 1000m [4]. This means that for ETR407, 138 RSE stations are needed.

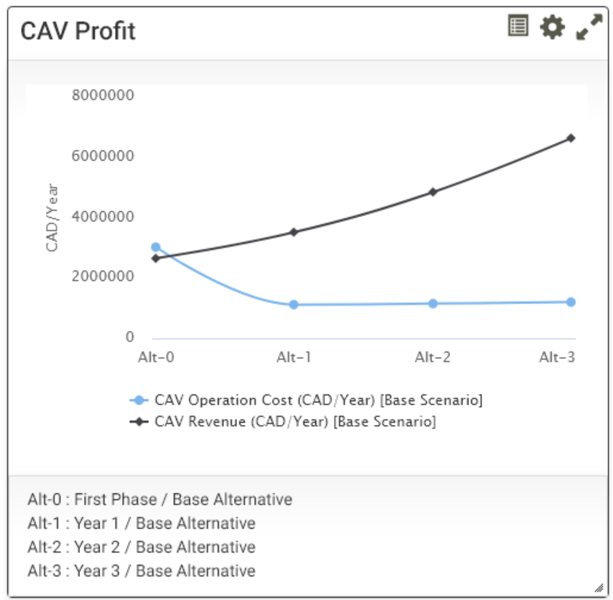


Figure 31 CAV Revenue, Road Owner is RSE owner, RSE at 1000m intervals.

After inserting the new numbers into the model, the cost and revenue curves were produced and Figure 31 shows the cost and revenue curves in this case. As the figure shows, we see that in the first year, the cost is higher than the revenue, which is logical as capital expenses are invested into the construction of the RSE stations. However, in the following years, the profit margin increases by a large value as the RSE outsourcing cost is eliminated and only the RSE operational expenses and the RSE depreciation values are incurred.

The assumption that the RSE will be constructed at 1000m intervals is based on the current standards. The actual construction might be at a smaller interval. Therefore, if the RSE stations will be placed at 500m intervals, in that case, 278 RSE stations are needed to cover the road.

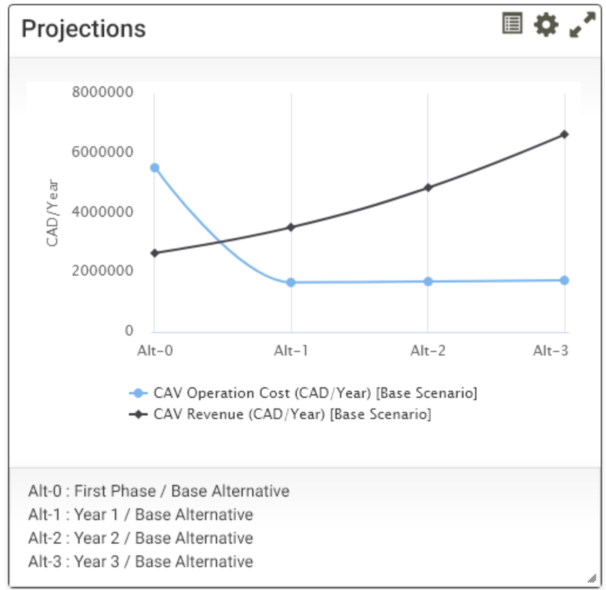


Figure 32 CAV Revenue, Road Owner is RSE owner, RSE at 500m intervals.

In this case we can see the impact on the investment in figure 32. It will still be profitable for the road owner to invest in that case. Although the EBITDA margin will be lesser than the previous scenario, the customer satisfaction levels will increase due to a much better and safer service, and in that case, the NPS will be closer to 100% which will reflect on revenue increase. For this option, it will still be profitable for the road owner to invest in RSE as a new business if they decided to construct one RSE station every 280 meters.

By comparing Figure 36 and 37, it is obvious that for the assumptions made, the road owner decision makers will have more long-term profits if they chose to invest in RSE to be owned by the Road Owner. The revenue and actual cost values at the real time of the CAV launch are still not the final accurate values, as no one can determine how much it will be exactly, however, the model is valid and by applying the actual values at any point in time, the decision makers can choose the best way to maximize shareholders' wealth.

Other road owners will also find this model beneficial. One of the main factors to decide on the investment is the number of RSE stations needed and the trip fees. The private roads could range from 91 Express Lanes in California USA which is 29 Km to the 138.7 Km of 407 ETR, or to any other road owner where the road length could reach up to 400 Km or more for example. However, most private roads that will offer CAV option will be in urban areas where the road length will not exceed 407 ETR.

In this chapter, the VMP model and all its products were discussed in detail. The CAV ecosystem was constructed and the "As-Is" and "To-Be" scenarios were evaluated. The products of the VMP model will allow business owners and decision makers to reduce the operational risks through deep understanding of the value creation and value exchange within the ecosystem. Another risk that is not covered by VMP tool is the service development risk. The business owner will incur costs for service development that include the extra cost of development due to many risks such as misalignment and scope creeps. In the following chapter, we will show how the UML use case diagrams will reduce such risks as it will provide a unified standard that will increase the business alignment and will provide service developers with the first step of service development, and consequently, reduce the cost and time of service development.

Chapter 5

The VMP is a very practical and sophisticated tool that allows business owners to have a clear view about value creation and value streams in a business ecosystem. However, the VMP does not cover the UML use case diagram creation. The importance of the UML use case diagram arises from the fact that it is a common architecture that programmers use to build the use cases and define the scenarios that the system follows to interact with business partners or customers. "The main advantages of using UML are that it is now a de facto standard for system description, it is easily understandable by non-experts, and it is well adapted for early stages of development" [40]. UML is a modeling language used as a standard to assist software and system developers to construct the software systems.

The main purpose of UML is to avail a graphical notation that can be used by object-oriented methods. The UML is regarded as reference that aligns the developers in an organization or a project, and help business owners achieve better quality, cost effectiveness, and time to market goals. There are many types of UML diagrams that are used by many organizations for the above purposes. summarized 13 UML diagrams that are commonly used by software development stakeholders [39]. In this research the focus is on the Use Case Diagram. The Use Case Diagram features use cases to describe the desired functional requirements of the system. The different business entities in the system are labeled "Actors". The actors could be the customer, the service provider, or the business partners. The intended functionality of the system is described by the "use cases".

The UML is usually prepared after the service is designed. The service design includes all entities that participate to create the service and the interactions between them. Without VMP business modeling, this process needs resources that will check the service design, talk to business entities, and decide how to represent the service for service developers. The risks of scheduling, and requirements changes can delay the execution of the services development. The automated production of UML diagrams from the VMP business model not only reduces the service development risks, but it also saves the resources needed for UML use case preparation and ensures proper alignment on the services and the business entities involved in their creation, or in other words, a value-based UML is more formal, while the currently produced UML is informal.

5.1 VMP-UML Tool Technical Requirements

To develop the tool that will convert the output of the VMP into UML, the technical requirements must be defined. In this section, the technical requirements that were used to develop the tool are reviewed.

The technical requirements are as follows:

1. Services UML

   The services are defined in the Value Stream Mapping (VSM) view of the VMP, for each service, the following procedure should be followed:

   a. The service is defined in “Value Stream”. The value stream name is the name of the service.

   b. Each activity inside the value stream is connected to the a “Competency Container”.

   c. The name of the competency container is the name of the partner, business owner, or customer. The name assignment is as follows:

      i. Emission Manager is a business partner to the TMC.

ii. TMC is a business partner to the Road Owner.

iii. The Road Owner is the business as presented in the business model.

iv. The CAV is the customer 1.

v. The ISP is a business partner to the Road Owner.

vi. The Traveler is customer 2.

vii. The RSE is a business partner to the Road Owner.

d. The activities inside the value stream are the action done by each entity and are summarized in Table 9 below.

Table 8 Roles and Activities

Emission Data		
Entity	Role	Activity
Emission Manager	Partner (to TMC)	Send Emission Data
TMC	Partner	Emission Data Processing
Road owner	Business	Integrate Emission Data
CAV	Customer 1	Use Emission Data
Variable Speed		
Entity	Role	Activity
TMC	Partner	Send TMC Variable Speed Data
RSE	Partner	Send RSE Data
Road owner	Business	Integrate Variable Speed Data
CAV	Customer 1	Adjust Driving Speed
Dedicated Lanes		
Entity	Role	Activity
TMC	Partner	Send TMC Dedicated Lanes Data
RSE	Partner	Send RSE Dedicated Lanes Data
Road owner	Business	Assign Dedicated Lanes
CAV	Customer 1	Drive in assigned lane
Traveler Data		
Entity	Role	Activity
ISP	Partner	Integrate Traveler Data
Road owner	Business	Permit ISP to send
Traveler	Customer 2	Receive Traveler Data

e. The competencies inside the competency container are not in scope for the UML diagram.

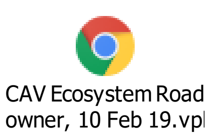
5.2 Structure and Algorithm

The following are the exact steps carried out to generate the UML diagrams.

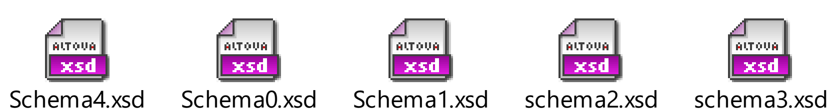
- Export and extract the VPK file,
- Search for the file that contains the diagrams “e.g. file name: @198b80@-93a4-49c4-91dd-dcc12f7b.json” found in the VPK file
- In the file search for a jason element called diagrams with “name": "Road Owner VSM" and type": "vdml_ValueStreamMapDiagram"
- Get the data element that contains xml and replace” =/” with “= “and then save it in a a text file with extension .xml, this is the file that will be used to extract the diagrams.

5.2.1 XMl structure

VPK



XSD XML structure



XML instance extracted from VPK file

VDMDiagrams.xml

5.2.2 Algorithm

- Convert the XML elements in the XSD to a set of classes using Java, this will be done by identifying actors, use cases and relation between them.
- Classes names: One for each complex element (To be listed)
- VDML to UML elements lookup table:

Table 9 shows how the use case elements are represented in the VDML schema, e.g. Activity represents the use case.

Table 9 Use Case Elements

VDML	UML	description
valueStream	Business use case boundary	
Activity	use case	
CapabilityContainer	Actors	
CausalRelationship	Association	relation between activity and capability container normal link
DeliverableFlow	Association	relation between activities

UML production Steps:

1- Using the XSD file, load XML elements as objects in memory.

All valuestream elements (Activities, containers and relations) are loaded as objects.

2- Get the relation between capability containers and activity

```
For each valueStream in the valueStreamMap
   For each activity in the value stream
         For each container in the container list //get main actor for each usecase
                  If container.incoming=activity.outgoing
                           {
                           Add(container name, activity. Actorlist,main)//
                  add(item,itemlist,type)
                           Break the loop
                           }
get the incoming relations to complete the actor –use case relation
For each valueStream in the valueStreamMap
   For each activity in the value stream a1
            For each activity in the value stream a2
                  If a1.activity.incoming= a2.activity.outgoing
                           {
                  Add(a2.activity.name, a1.activity. actorlist)
                           }
```

3- ADD below string to the file

“@startuml

left to right direction

skinparam packageStyle rectangle”

for each actor in the value stream

ADD“actor “+ actor name

then add “rectangle VariableSpeed {”

for each activity in the activity list

for each actor in the activity

ADDactivity name +”--” actor ADD” }

@enduml”

Output for variable speed is displayed in Figure 33.

```
@startuml
left to right direction
skinparam packagestyle rectangle
actor TMC
actor RoadOwner
actor RSE
actor CAV

rectangle VariableSpeed {
TMC -- (Send TMC Variable Speed Data)
RSE -- (Send RSE Data)
RoadOwner--(Integrate Variable Speed Data)
RoadOwner -- (Send TMC Variable Speed Data)
RoadOwner--(Send RSE Data)
(Integrate Variable Speed Data)--CAV
(Adjust Driving Speed)--CAV
}
@enduml
```

Figure 33 UML Output for Variable Speed

5.3 Produced UML Use Case Diagrams

The UML product of the previous process is VDML-based. The following figures represent the use case UML for the services of the VMP model.

Figure 34 shows the Variable Speed service use case UML based on the VMP model. The actors are the Road Owner, RSE, TMC, and CAV as the customer. The data displayed in the UML use case scenario is the same data from the VMP model.

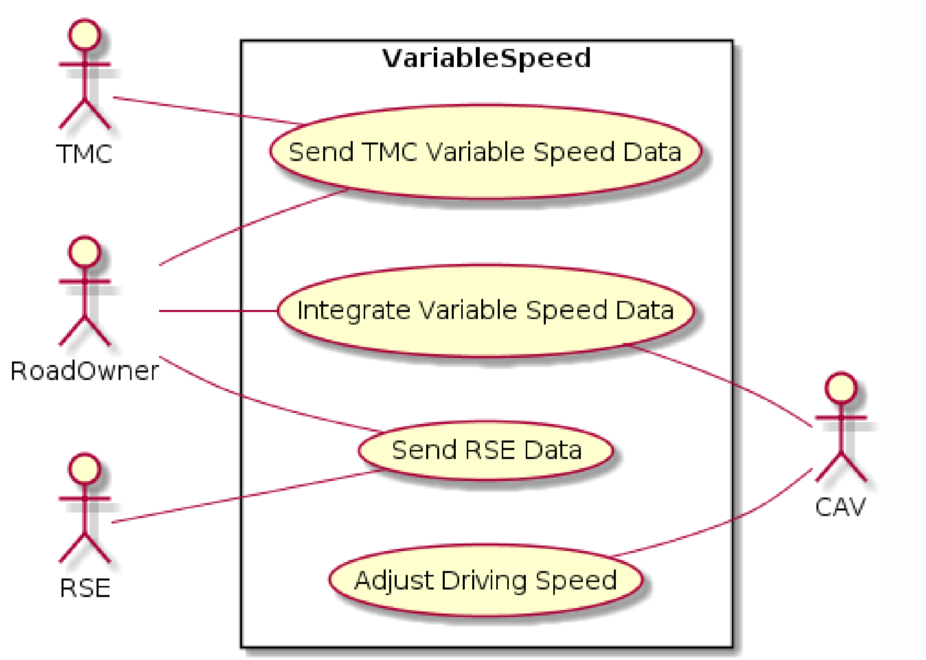


Figure 34 VMP-Based Variable Speed UML

In a similar manner, VMP-based dedicated lanes use case UML is shown in Figure 35 and VMP-based emission data use case UML is shown in Figure 36. Service developers in the road owner business will use this UML as a reference for the automation of this service and consequently, achieve the link between enterprise architecture models and enterprise ontology formal models.

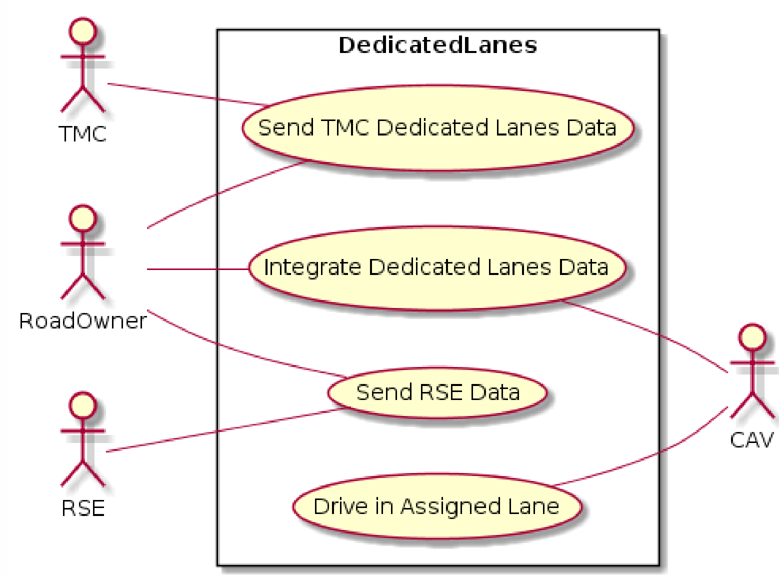


Figure 35 VMP-Based Dedicated Lanes UML

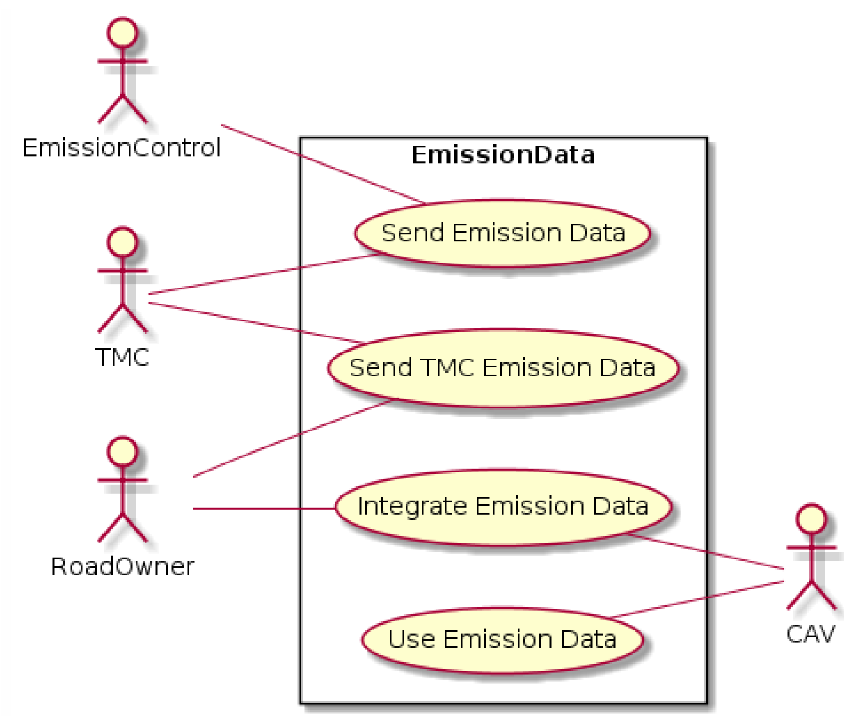


Figure 36 VMP-Based Emission Data UML

Chapter 6

6.1 Conclusion

The CAV is one of the main applications of the smart city initiative. Many business entities will be involved in the CAV operations. The conventional business analysis methods and models are not enough to have a clear description about the value creation and value exchange within the ecosystem. A value-based model is needed to help decision makers take sound decisions and to define proper risk management strategies through a more thorough risk identification.

A methodology has been defined to be a reference for future work related to CAV ecosystem analysis and modeling by using the VMP tool. The VMP model has been constructed to allow the business owners to take sound decisions. The model has described the value creation and value exchange in the CAV ecosystem and has been used to evaluate the business investment for the Road Owner. The VMP model has presented the “As-Is” and the “To-Be” business situations regarding the CAV readiness.

The model has provided the business owner with deep understanding of the ecosystem and the business operations, which in turn leads to more sound risk definition and consequently, a good selection of proper risk management strategies. The ecosystem has explained the actors of the system, the main business partners and the customers. It has also shown how the value is exchanged in the ecosystem amongst all players even beyond the direct business partners of the road owner, such as how the ISP exchanged important values with ISP business partners that are not in direct contact with the road owner, therefore, the road owner could decide on transferring the risks of such values to the ISP.

The value stream mapping has revealed how the services provided to the CAV and the traveler are streamed in the ecosystem. The competencies used to create these values have been displayed for every business partner, for the road owner, and for the customer. This has helped the road owner to define which areas could have potential risks that would threat the service creation. Moreover, the business strategy map has helped the decision makers in visualizing the cost structure of their business, how the revenue is generated, and which competencies are involved. This has allowed the business owner to have better assessment of the risks involved in profit creation, such as cost variations.

The model has supplied necessary information to assist the road owner decision on investing in the RSE business or outsource the activity based on the vision and the financial status of the business at the time of the decision. The model has provided value-based analysis and has considered customer satisfaction based on NPS. The knowledge provided from the model will assist the business decision makers to have a thorough value-based understanding of the “As-Is” and the “To-Be”, which in turn will be basis for better risk identification and consequently risk management. The model can be used to evaluate the CAV business decisions from the road owner perspective, and it can be used for other businesses in the ecosystem as well.

Moreover, a tool has been developed to produce Value-Based UML use case diagrams. This would save time and resources for the road owner that could have been consumed to ensure that UML use case diagrams are based on the VMP modeling and would reduce the service development risks.

6.2 Recommendations

The innovated methodology used in this research can be used for studying the CAV ecosystem within the defined scope of this research. It will help the researchers to construct similar models and investigate the "As-Is" and the "To-Be" business situations. Future researchers are recommended to use this methodology for the CAV industry analysis from Road Owner, RSE, ITS, or ISP perspective.

Based on the model projections, it is more profitable for the road owner to invest in RSE rather than outsourcing the RSE operation. Considering the model outcome, decision makers would opt for the RSE investment option as it is more profitable on the long-term. Of course, the decisions might be affected by actual cash flow and investment portfolio of the business at the time of the decision, however, the model gives the decision makers deep understanding of the ecosystem and the exchanged values with business partners and with the customers.

6.3 Future Work

The methodology can be used to construct CAV ecosystem and investigate the different actors in the system. New services might be innovated and added to ARC-IT Version 8.2, which will consequently have newer version, and this will reflect in the initial investigation of the services and the ecosystem construction.

The model was constructed for a future business based on the assumption mentioned earlier. The actual data at the time of CAV investment might vary in terms of new enterprises that might be needed, or te cost of construction of the RSE equipment for example. Also, the discussion around the RSE or the 5G usage is still not finalized at the present time. The future work will include adding more enterprises to the ecosystem if necessary. Also, new values might be exchanged in the system in the future, and those can be added to the VMP model. The costs will be more accurate as we come closer to actual project execution as it will be based upon actual peds not estimated values, consequently, costs will be adjusted to give better forecast.

The UML tool can be used for use case diagram generation for other future services that will be added to the VMP model. This will assist the programmers to have a common reference for service development and will ensure the alignment for the business and within the ecosystem.

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Appendix A

Table 10 Value Stream Mapping, Services Details

Shape	Element Type	Target Element
Assign Dedicated Lanes	Activity	Assign Dedicated Lanes
CAV Dedicated Lanes	Activity	
CAV OBE	Competency	
CAV OBE	Competency	
CAV Variable Speed	Activity	CAV Variable Speed
Connected Device	Competency	
Dedicated Lanes	Value Stream	Dedicated Lanes
Emergency Notification	Activity	
Integrate Traveler Data	Activity	
Integrate Variable Speed Data	Activity	Integrate Variable Speed Data
ISP Agreement	Activity	
ISP DC	Competency	
Online financial support	Activity	
Receive Traveler Data	Activity	
Road Owner Billing	Competency	Road Owner Know-How
Road Owner Billing	Competency	
Road Owner Billing	Competency	
Road Owner DC	Competency	Road Owner DC
Road Owner DC	Competency	
RSE Data	Activity	RSE Data
RSE Data	Competency	
RSE Dedicated Lanes	Activity	RSE Dedicated Lanes
RSE Surveillance	Competency	
Send Forecast	Activity	
TMC dedicated Lanes	Activity	TMC dedicated Lanes
TMC Surveillance	Competency	
TMC Surveillance	Competency	
TMC Variable Speed Data	Activity	
Traveler Data	Value Stream	Traveler Data
Update Parking	Activity	

Table 11 CAV Ecosystem, Values Details

CAV	Enterprise	CAV
CAV Operation	Value Proposition	CAV Operation
CAV Trips	Value Proposition	CAV Trips
Emergency Data	Value Proposition	Emergency Data
Emergency Manager	Enterprise	Emergency Manager
Emission Control	Enterprise	
Emission Data	Value Proposition	
Emission Data Cost	Value Proposition	
Enforcement Center	Enterprise	
Feedback	Value Proposition	Feedback
Financial Data	Value Proposition	Financial Data
Financial Manager	Enterprise	Financial Manager
Fleet Count	Value Proposition	
Fleet Data	Value Proposition	
ISP	Enterprise	ISP
ISP Connections	Value Proposition	ISP Connections
ISP Data	Value Proposition	ISP Data
ISP Data Revenue	Value Proposition	ISP Data Revenue
ISP to other Data	Value Proposition	ISP to other Data
ITS	Enterprise	
ITS Data	Value Proposition	
ITS Data Cost	Value Proposition	
Other ISP	Enterprise	Other ISP
Other ISP Cost	Value Proposition	Other ISP Cost
Other ISP Data	Value Proposition	Other ISP Data
P Data Cost	Value Proposition	P Data Cost
Parking Data	Value Proposition	Parking Data
Parking Manager	Enterprise	Parking Manager
Road Owner	Enterprise	Road Owner
RSE	Enterprise	RSE
RSE Cost	Value Proposition	RSE Cost
TMC Cost	Value Proposition	TMC Cost
TMC Data	Value Proposition	TMC Data
TMC-RSE Cost	Value Proposition	
Traffic Violations	Value Proposition	
Transactions	Value Proposition	Transactions
Transit Fleet Manager	Enterprise	
Traveler	Enterprise	Traveler
Traveler Info	Value Proposition	Traveler Info
Traveler Trips	Value Proposition	Traveler Trips
Violations Contacted	Value Proposition	
Weather Data	Value Proposition	Weather Data
Weather Data Agreement	Value Proposition	Weather Data Agreement
Weather Service Provider	Enterprise	Weather Service Provider

Appendix B

1 Research Methodology

As the information technology penetrated many areas of human interest, many applications evolved, and with that, a lot of ambiguities were raised. One of the main challenges was to define frameworks for the design science in the area information's systems. "Acquiring such knowledge involves two complementary but distinct paradigms, behavioral science and design science "[14]. The purpose of the behavioral science paradigm is to define and validate theories that describe the interactions between people and technology in the information systems. Such theories guide researchers and managers to increase the efficiency of the information systems and achieve its goals and; consequently, it enhances the performance of organizations. The output of this analysis is usually used as feedback to the design of the systems in hand. Design science paradigm is concerned with innovative solutions in the information systems. Such solutions extend the boundaries of organizations and services provided to end users. A very important consideration with design science research is that it must be differentiated from building an information system. Innovation is the differentiator. Building a new system with existing knowledge is not considered a design science research.

Hevner et al. [14] stated that the importance of both behavioral science and design science should be considered for information systems research. They presented a framework for design science and information system research.

Figure 37 [14], represents the proposed framework. The environment defines the area under research where a certain phenomenon occurs and necessitates IS research to be carried out. Although the model describes such an environment as a space that contains

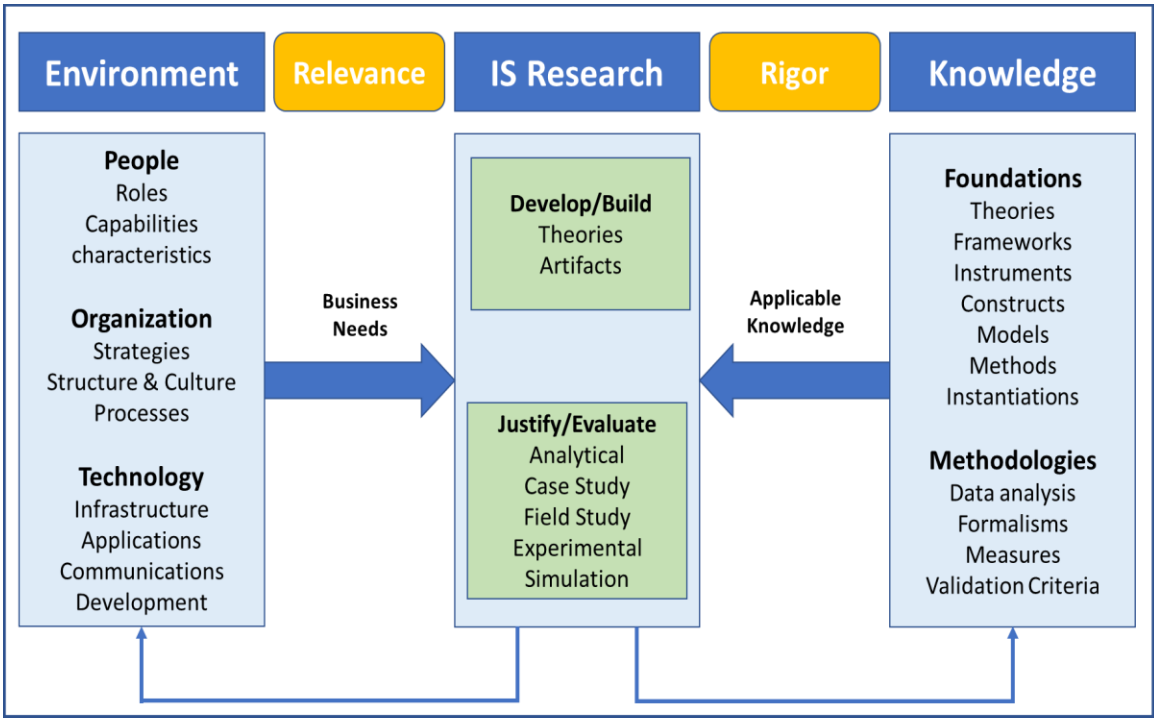

Figure 37[14] Information System Research Framework

people, organizations, and technologies, such an environment could vary between a single organization that contains people and technologies, or multiple organizations that operate in the same space, one example for that is ITS where many organizations collaborate to deliver services that add value to the community. The people in the environment part are meant to be the people working for the organizations; they absorb the organization's strategies, culture and business goals, and reflect them on their respective roles. The needed capabilities of the workforce and the characteristics that shape the organization's culture are also considered in this area. The technologies that are implemented in such organizations include the infrastructure, the applications used, the communications that facilitate the business flow both inter and intra company, and the development capabilities of the workforce. Putting all these factors into consideration would result in a fuller understanding of the business challenges that arise and feed the research process.

The IS research is carried out to overcome the business challenges. There are two phases that complement each other: *Develop and Justify* theories that predict or explain phenomena associated with the business challenges. Design science aims at creating artifacts and evaluating their performance with respect to the business challenges in hand. "*the goal of behavioral science research is truth; the goal of design science research is utility*" [14].

The theory and the artifact both need many iterations and assumptions until the desired outcome is achieved. This necessitates the need for a knowledge base where all research and design data are stored for future references. The knowledge base has two main areas: foundations and methodologies. The foundations part contains theories, frameworks, instruments, constructs, models, methods and instantiations that are sued in the develop phase of the IS research area. The methodologies part contains the data analysis, formalisms, measure and validation criteria that are used to judge the usefulness of the research in terms of answering the business need or solving the business challenges. Although computational and mathematical methods are usually used for design science, the use of empirical techniques might also be needed. IS research also includes assumptions that are made in iterations, and that shows the importance of knowledge base as it holds the key to narrow down the uncertainties that exist mainly due to the assumptions made. In the following section, we review the design science in IS research guidelines that were introduced based on the previous model and presented in [14].

1.1 IS Research Guidelines

There are seven guidelines that guide the flow of the IS research: Design as An Artifact, Problem Relevance, Design Evaluation, Research Contributions, Research Rigor, Design as A Research Process, And Communication Od Research. The guidelines correlate to the IS research framework.

Design as an Artifact

The definition of an IT artifact in this context is that it contains instantiations, models, constructs and the methods that are applied in the IT development. Artifacts are innovations that help the organization overcome business challenges or achieve business goals. The design research is expected to produce a valid artifact. In some cases, successful or widely used artifacts are not initially anticipated to achieve such success. To build a viable artifact, the requirements must be defined and finalized properly; this is an important step as defining clear business needs is the key to avoid ambiguities that would arise upon the construction of the artifact. This also help to define the main purpose of the artifact and is used as basis of the evaluation of its performance.

Problem Relevance

The business analysis is conducted by assessing the "as is" situation and defining the "to be" situation. The purpose of IS research is to have the needed knowledge and reach the appropriate level of understanding that are needed to produce an artifact that helps the reach the desired situations. The IS research must introduce solutions to relevant business problems.

Design Evaluation

Evaluation of the produced artifact is a pivotal component of the IS research. The evaluation criteria are decided based on the agreed requirements. "*IT artifacts can be evaluated in terms of functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization, and other relevant quality attributes*" [14].

The artifact must fulfill its purpose, and it should be within the boundaries of the overall system consideration that it should operate within. For example, an IT product should meet the business requirements, the technical security requirements, the technical operations requirements, and, in some applications, the customer service requirements.

Table 12 [14] IS Research Guidelines, Design Evaluation

Method	Details
Observational	Case Study: Study artifact in depth in business environment
	Field Study: Monitor use of artifact in multiple projects
Analytical	Static Analysis: Examine structure of artifact for static qualities
	Architecture Analysis: Study fit of artifact into technical IS structure
	Optimization: Demonstrate inherent optimal properties of artifact or provide optimality pounds on artifact behavior
	Dynamic Analysis: Study artifact performance
Experimental	Controlled Experiment: Study artifact in controlled environment
	Simulation: Execute artifact with artificial data
Testing	Functional (Black Box) Testing: Execute artifact interfaces to discover failures and identify defects

	Structural (White Box) Testing: Perform coverage testing of some metrics in the artifact implementation
Descriptive	Informed Argument: Use information form the knowledge base to build a convincing argument for artifact utility
	Scenarios: Construct detailed scenarios around the artifact to demonstrate its utility

The evaluation provides regular feedback to the design and implementation of an artifact. If any of the required attributes of the product is not achieved, or needs enhancements, the design is revisited, and the artifact is modified to meet the expected results.

The evaluation methodologies are stored in the knowledge base. Table 12, [14], shows a summary of the evaluation methodologies. It is important to choose the appropriate method for the produced artifact. For example, in IoT applications, a huge number of sensors is deployed to take a physical measurement and relay the data back to the base station or the sink node. The evaluation of IoT sensors can only be done through simulation, as it is not feasible to deploy hundreds and maybe thousands of sensors in real environment to evaluate their performance after applying a new software.

Research Contributions

The efficiency of the design science is determined by how much it adds value to the area of concern. The design science research contribution to the design artifact should be clear and it should be verified.

There are three types of research contributions

1. The Design Artifact. The artifact itself could be the contribution of design science research. It could be a solution that helps transfer an organization from the "as is" to the "to be" situations. The artifact could also add value to the knowledge base by adding new ideas to it, or by using existing knowledge in new innovative areas.
2. Foundations. Referring to Figure 42, the innovation of new models, methods, construct or instantiations could be regarded as a positive contribution to the knowledge base.
3. Methodologies. Applying evaluation methods to the artifact would significantly add value to the methodologies in the knowledge base area. The evaluation techniques could be analytical, case study, experimental, field study or simulation as discussed earlier.

The research must add a new way of solving an unsolved problem.

Research Rigor

Rigorous methods must be applied for the construction and the evaluation of the designed artifact. Appropriate data collection and data analysis techniques that are applied in behavioral science research have led to the sacrifice of relevance in the IS research. On the other hand, applying mathematical methods in design science would neglect the impact of the environment in which the desired system operates, consequently, rigor is sacrificed. It is imperative for IS research paradigms to be both rigorous and relevant. This can be achieved through the careful selection of techniques from the knowledge base; a task that relies mainly on the skill of the researcher.

Design as a Search Process

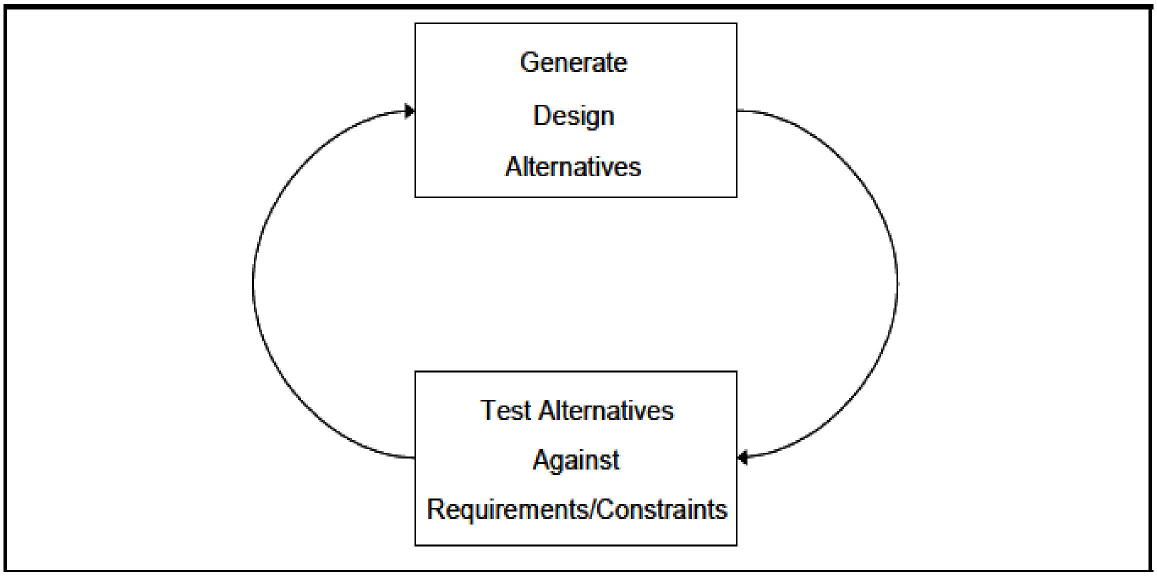

Figure 38 [14] The Generate/Test Cycle

Figure 39 [14] The Generate/Test Cycle

Figure 40 [14] The Generate/Test Cycle

Figure 41 [14] The Generate/Test Cycle

The design science is performed to overcome business challenges to achieve the business goals, this could be expressed as the problem that necessitated the design science. *"Problem solving was defined as a behavioral process which makes available a variety of response alternatives for dealing with a problematic situation and increases the probability of selecting the most effective response from among these alternatives"* [15]. Iterations are needed to reach a final artifact that fulfills its purpose. Through the iterations, different alternatives are discussed and implemented if necessary. Figure 38 [14] shows the Generate/Test cycle [16].

As it states, after completing the artifact, it should be tested against the requirements putting into consideration any operating constraints, for example, security constraints. This feeds back to the design phase where design alternatives are generated to modify the produced artifact.

Communication of Research

One of the main challenges in IT organization is to communicate the IT products to commercial teams and to technical teams as well, this's mainly because they don't speak the same language. This's the same case with design science research where the artifacts must be technical-oriented and business-oriented audiences.

Presenting the artifact to technical audience with technical details about it will help the technical teams to understand the artifact and support its operation properly. This also help researchers to build on the artifact to come up with new innovations that add to it, and answer to more evolving business needs.

On the other face of the coin, presenting the artifact to management should show its benefits and impact on the organizational performance. It should also entail the system requirements for efficient operation.