REPUBLIC OF TURKEY
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

NEXT GENERATION EMERGENCY NOTIFICATION SYSTEM: MODEL DEVELOPMENT BASED ON THE OPTIMAL ARCHITECTURE SELECTION OF EUROPEAN COUNTRIES AND IN-VEHICLE ECALL SYSTEMS IMPLEMENTATION

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Ph.D. THESIS
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A thesis submitted by Ahmet APAK in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** is approved by the committee on 10.11.2017 in Department of Control and Automation Engineering Program.

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This Ph.D. thesis is written by Ahmet Apak with Asst. Prof. Dr. İlker Ustoglu as ‘Next Generation Emergency Notification System: Model Development Based on the optimal architecture selection of European Countries and In-vehicle eCall system implementation’.

The First Approach to create the Ph.D. thesis is to create the Hardware in the loop and software in the loop system approach about eCall equipped vehicle system including not only scientific research but also technical research. But the condition changes such as company relations etc. in the thesis periods give a direction to the thesis to be technical and economical researchers of the topic for in-vehicle systems and the country infrastructure eCall systems. Its technical research includes the development implementations of automotive engineering and its economical research includes the cost modeling approaches via controlling simulations. The combination of technical and economical researches gives the results of system integration studies with the patent applications, articles and journal releases. It gives a commend also about the whole eCall system scenarios including vehicle systems, country architectures.

This thesis’ topic including overall system study is inspired by the study in Germany which is published in 2005 by ‘VDI-VDE-IT Ifv Köln’ as ‘exploratory study on the socio-economic impact of the introduction on Intelligent Safety Systems in Road Vehicles’. This study focuses on the intelligent vehicle systems based on socio-economic impact when this thesis focuses on the eCall systems including not only vehicle system approach but also country architecture studies. The country architecture studies are supported by the EENA and HeERO projects.

The thesis’ articles and journals are focus on eCall equipped vehicle system and the cost model study including vehicle & road safety systems & optimal architecture selections of the EENA architectures after eCall equipped vehicle regulations; when the patent applications of the thesis are focus on the eCall equipped vehicle systems and functional & technical descriptions of the new eCall system structures for EENA, Architectures.

Ph.D. candidate does not want to have special thanks to anybody. He wants to thanks for the support who makes a valuable contribution to the thesis.

November, 2017

Ahmet APAK

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LIST OF SYMBOLS

A	Population Rate Code Letter for 19K-100K population
A1	PSAP Filtration Rate_min value of 19K-100K Population-Based Calc.
A2	PSAP Filtration Rate_max value of 19K-100K Population-Based Calc.
A3	PSAP Filtration Rate value of 19K-100K for Call event Based Calculation
bt	Depreciation Period
Number_B	Billion, 10^9
B	Population Rate Code Letter for 100K-140K population
B1	PSAP Filtration Rate_min value of 100K-140K Population-Based Calc.
B2	PSAP Filtration Rate_max value of 100K-140K Population-Based Calc.
B3	PSAP Filtration Rate value of 100K-140K for Call event Based Calc.
C_Number	eCall device inside equipment abbreviations of Figure 4.6
C	Population Rate Code Letter for 140K-240K population
C1	PSAP Filtration Rate_min value of 140K-240K Population-Based Calc.
C2	PSAP Filtration Rate_max value of 140K-240K Population-Based Calc.
C3	PSAP Filtration Rate value of 140K-240K for Call event Based Calc.
c0	Fuel Formula Constant Parameter; energy efficient parameter
c1	Fuel Formula Constant Parameter; drag-term
c2	Fuel Formula Constant Parameter; ideal fuel rate
CT	Cellular Tower
CTN	Cellular Tower Network
CO2	Carbon dioxide
db	Communication Filename
dr	Discount Rate
dR	Diffusion Rate
Drsf	Driver Reaction Shift Forward
EU-25	25 European Union Countries
€	Euro
€/h	Euro is divided by Hour
€/100km	Euro is divided by 100 kilometers
F	Function of Vehicle Systems
FS	Function of Infrastructure Systems
I	Input
IP	Protection Identity
ISI	Infrastructure System Input
K	Thousand, 1000
M	Million, 10^6
M/A	Manual and/or Automatic
NOx	Nitrogen Oxide
O	Output
OI	Output Infrastructure

P	Process
PF	Process Flow
PFE	Ecall Process Flow
R	Regulation
T	Thousand, 1000
T.F.	Transfer Function
v	Speed
V	Voltage
V+	Supply Voltage
V-	Ground, Minus Voltage
X	Small Size PSAP Acronym
Y	Medium Size PSAP Acronym
Z	Large Size PSAP Acronym
●	Strong Relation symbol in Figure 4.8
○	Weak Relation symbol in Figure 4.8
uP	unit Processor
w.out	without
yd	Days of the year

LIST OF ABBREVIATIONS

ACur	Accident Cost Unit Rate
ACEA	European Automotive Manufacturer Association
Ad	Administrative Costs
APV	Annuity Present Value, Net Benefit
As	Accident severity
ASIC	Circuit Process type
Auto	Automatic
BCR	Benefit to Cost Ratio
BMW	Bayerische Motoren Werke
CAD	Computer Aided Dispatch
CAN	Control Area Network Communication Type
CAN-Bus	Vehicle CAN Communication
CEN	European Committee for Standardization
CCo	Fuel Consumption Constant
CMS	Call management software
CPE	Customer Premise Equipment
DCOVR 6	Sigma Tool: Define-Characterize-Optimize-Verify-Control
DMAIC 6	Sigma Tool: Define-Measure Analyze Improve Control
dh	Daily Hour
EC	Emission Cost
ECALL	Emergency Call
Eco	Emission Constant
ECur	Emission Cost Unit Rate
EENA	European Emergency Number Association
EF	Emission Factor
Eq.Rate	Equipment Rate
EMC	Electromagnetic compatibility
EN	European Standards
ERO	Emergency Response Organization
EVS	Equipped Vehicle Stock
EU	European Union
ETSI	European Telecommunication Standards
FC	Fuel Consumption
FCC	Fuel Consumption Cost
FCf	Fuel Consumption Factor
FCur	Fuel Consumption Cost Unit Rate

GIS	Geographical Information System
GUI	Graphical User Interface
GPS	Global Positioning System
GSM	Global System for Mobile Communication
GM	General Motors
GNSS	Global Navigation Satellite System
HeERO	Harmonised Emergency Call European Pilot
IDADA	Applus+ Automotive Technology Manufacturer
IOS	Processor System
IEEE	Institute of Electrical and Electronics Engineers
IET	Intelligent Transport Systems Magazine
IRTAD	International Road Traffic and Accident Database
ISc	Infrastructure System Cost
ISO	International Standards for Organizations
ITST	Intelligent Transport System Telecommunication
IVSS	Intelligent Vehicle Safety Systems
Lc	Labor Cost
LIN	Vehicle Communication Type
msc	Membership Prices
NCAP	New Car Assesment Programme
nad	Number of Available Days
nce	Number of Call events
NENA	National Emergency Number Association U.S.
NoAC	Numbers of Accident
ntd	Number of Training Day
np	Number of PSAP
npw	Number of PSAP Worker
ntd	number of training days
OEM	Organization of Equipment Manufacturer
OSC	Overall Infrastructure System Cost
PCM	Power Control Module
PSAP	Public Safety Answering Point
PTr	PSAP Training Cost
PW	PSAP Worker-Equipments
RCL	Robustness Check List
RDV	Response Dispatch Variant
SENT	Vehicle Communication Type
SAE	Society of Automobile Engineers
TC	Time Cost
TCur	Time Cost Unit Rate
TS	Telecommunication Standard
TIME	Events of Wanted persons etc.. in emergency services
U.K.	United Kingdom
UPS	Uninterrupted Power Supply Module
U.S.	United States of America
USCAR	United States Council for Automotive Research
VAC	Vehicle Accident Cost
Vm	Vehicle Mileage
VS	Vehicle Stock
wh	working hour

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ABSTRACT

NEXT GENERATION EMERGENCY NOTIFICATION SYSTEM : MODEL DEVELOPMENT BASED ON THE OPTIMAL ARCHITECTURE SELECTION OF EUROPEAN COUNTRIES AND IN-VEHICLE ECALL SYSTEM IMPLEMENTATION

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Ph.D. Thesis

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According to International Road and Accident Database, IRTAD member countries' road fatalities are between 3 and 13 in 2012 via 2014 report. This rate is higher in Turkey. Due to this reason, Countries try to create new regulations to decrease these rates. The European Union Parliament introduces the legislation EU-2015/758 which means the obligation of eCall equipped vehicles in the European countries. It includes the new PSAPs (Public Safety Answering Points) structures will be ready for the new system in 2017 and the eCall equipped vehicles will be ready in 2018. This update and modification will be applied in Turkey after 2018. Ecall equipped vehicles in the international area such as U.S., Europe are used in the few volumes. The few volume vehicles are produced with respect to research and product developments, be accessories in the luxury cars. GM Onstar, BMW assist can be given as an example of the product. After eCall equipped vehicles in the countries, the eCall system will be an obligation in the vehicle systems. In vehicle eCall system which will be applied as an obligation after the related regulations will be activated manually or automatically when the accident occurs. When automatic eCall device is processed without any external input which means it can be activated automatically, manual eCall device is processed with external input such as driver or passenger touch force on the eCall measurement unit button. After activation process, the data sets are processed in eCall system in the vehicle and it is transferred to the cellular tower network. By the way, eCall device in the vehicle receives the vehicle signals of airbag, ignition signal, wake signals etc. When the cellular tower network chooses which cellular tower is the best alternative to take the required accident data via its storage capacity, signal power status; the chosen cellular tower takes the required accident data. It processes the data, transmits it to the related data format, stores them and sends to the related PSAP via a communication network. PSAPs in the new system will be varied as 112 PSAPs, manual eCall PSAPs and Automatic eCall PSAPs. Manual eCall PSAPs are giving the responses to the accidents of the vehicles including manual eCall device. On the other hand, Automatic eCall PSAPs are giving the responses to the accidents of the vehicles including auto eCall device. Next, PSAP takes the accident info, process it and forward to the related rescue services and these services define the accidents to the rescue service vehicles. After the new system updates in the vehicle system and the modifications of the country architectures of European Emergency Number Association (EENA), traffic and road management system and its infrastructures will be updated or created. The vehicle application of eCall system will be adapted to the vehicles with this new structure. Thanks to this project, in-vehicle eCall application is implemented with its operational requirements. On the other hand, the country architectures will be varied via having different PSAP and rescue service usages. The eCall PSAPs, 112 PSAP and Rescue Service units can be integrated as integrated units or they can be set up as different units. The aim of this thesis is to implement the eCall system with its robustness system requirements in the vehicle structure and the optimal eCall system architecture selection of a new feature of EENA, Systems for the European Countries.In addition, mounting location of eCall device in the passenger cars and cost reduction items are also analyzed in the study.Moreover, The architecture selection of the Countries is explained by the filtration process. The filtration is enabled by the cost model study which includes intelligent vehicle and road safety systems and infrastructure systems.

Keywords: Emergency Call System, 112 PSAP, Rescue Services, Emergency Call Unit, eCall

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ÖZET

YENİ NESİL ACİL YARDIM SİSTEMLERİ: AVRUPA ÜLKELERI MİMARİLERİNİN MODELLEME YÖNTEMİ İLE OPTİMUM YAPISININ YAYINLANMASI VE ARAÇ İÇİ ACİL YARDIM SİSTEMİ UYGULAMALARININ YENİ MİMARİSİNİN DAYANIKLI YAPI İLE TANIMLANMASI

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Uluslararası kaza ve yol veritabanı (IRTAD) üyesi ülkelerin 2014 yılında yayınlanan 2012 verilerini içeren raporunda, IRTAD üyesi ülkelerde yüz bin kişilik bölge verilerinde, yol kazalarındaki ölüm oranları 3 ila 13 kişi arasında değişmektedir. Türkiye'de ise bu oran daha yüksek bir değer almaktadır. Ülkeler, ölüm ve kazaları azaltmak adına çeşitli düzenlemeler yapmakta, ortaya uluslar arası standardlar koyup, yayınlamaktadırlar. Bu bağlamda, Avrupa Parlamentosunun 2015/758 sayılı yasası gereğince Avrupa'da 2018 yılı Mart ayında yürürlüğe girecek biçimde acil yardım servisleri yeniden yapılandırılacaktır. Dolayısı ile bu tarihten itibaren Avrupa Birliği sınırları içerisinde acil yardım çağrı üniteli araçlar yol almaya başlayacaktır. Türkiye bu yeni düzenlemeye 2018 yılını izleyen yakın bir tarihte uyum gösterecektir. Bu bağlamda acil yardım çağrı üniteli araç kullanımları başlayacak, acil yardım altyapıları güncellenecek ya da mevcut sistemler yeniden yapılandırılacaktır. Araç acil çağrı sistemleri herhangi bir regülasyon zorunluluğu olmaksızın Avrupa, Amerika ve bazı dünya ülkelerinde Otomotiv Firmaları tarafından az bir araç stokuna; geliştirilmesi, test edilmesi ve donanımı yüksek araç ekipmanı olarak sunulması için uygulanmaktadır. Bu araç sistemlerine örnek olarak General Motors'un OnStar sistemi, BMW'nin BMW Assist sistemleri örnek olarak verilebilir. İşte bu araç sistemlerinin regülâsyonlar sonrası zorunlu hale gelmesi ile tüm araçlar ve markalarında regülâsyonların devreye girdiği ülkelerde uygulanmaya başlanacaktır. Regülâsyonlar sonrası kullanıma girecek bu sistemde; araç kazası gerçekleştikten sonra önce kara taşıtı acil çağrı ünitesi manüel ya

da otomatik olarak devreye alınır. Otomatik acil çağrı ünitesi üzerinde herhangi bir başlatma düğmesi olmayan, kazayı acil çağrı cihazı iç ünitesi ve araçtan gelen hava yastığı vb. sinyal aktivasyonları ile tespit eden, harici bir müdahale olmadan kaza verilerini haberleşme kulesine aktaran ünite tipidir. Manüel acil çağrı ünitesi ise bir aktivasyon düğmesine sahip ve ancak bir dış etki ile etkinleşen çağrı ünitesi tipidir. Acil çağrı ünitesinin çalışma şekline bağlı olarak, veri akışı bu iki cihaz tipinden birinin yapısına göre gerçekleşir. Bu veri akışının, kara taşıtı acil çağrı ünitesinde gerçekleşebilmesi için, eş zamanlı olarak; acil yardım girdisi (emergency call wake-up signal) ve araç tetikleme sinyali (vehicle ignition signal) acil çağrı ünitesine iletilmiş olması gereklidir. Ayrıca acil yardım çağrı ünitesi araç ana bataryası tarafından beslenebilir olmalıdır. Kaza yapan aracın, araç acil çağrı ünitesinde işlenen verileri; araç konumu, araç şase numarası, kaza zamanı, araç ivmesi, kazanın ehemmiyet katsayısı ve uluslar arası standardların ilgili acil yardım haberleşme yönetmeliklerinde (EN15722) belirtilen asgari veri kümesine sahip olmalıdır. Elbette, daha geniş veri kümeleri de oluşturulabilir. Verilerin acil çağrı ünitesi içerisinde işlenmesi sırasında; veri birimleri (data layers) uygulama yapısı (application framework) ile işletim sisteminde işlenirken, Linux−kernel gibi farklı işletim sistem ve yazılım bölümleri ile kaza anı ve öncesi hakkında veri toplanması sağlanır. Yanı sıra; yazılım kütüphanesi, yüzey yazılımı (surface framework) ve medya yapısı (media framework) yazılımın çalışmasını destekleyen yazılım bölümleridir. Tüm bu eş zamanlı gelişen donanımsal, sinyalsel ve yazılımsal işlevler gerçekleştikten sonra, kazaya ait veri setleri Haberleşme kulesi veri ağına iletilir. Haberleşme kulesi ağlarından haberleşme kulesine veri aktarımı gerçekleşir; yeni mimari ile yeniden yapılandırılmış olan Acil Çağrı Merkezi Kontrol Oda veya Binasına iletilir. Yeni yapılanmada 112 servisi çağrı cevap birimi, manüel ve otomatik kara taşıtı kaza cevap birimleri; Acil Çağrı Cevap Servisi sistemleri ile; kara taşıtı kazası acil yardım çağrısına ait veri setlerini işler ve çağrılarını cevaplarlar. İşlenen veri setleri bu üç birim ve/veya birimlerce kurtarma servisleri olan polis, ambulans ve yangın birimlerine transfer edilir. Burada veriler, bu kez kurtarma servislerinin veri tabanında depolanır, işlenir ve ilgili ilk yardım ekip araçlarına aktarılır. Bu sayede ilk yardım taşıtlı ekipler, kazanın olduğu bölgeye harekete geçer.İşte Araç içi Acil Yardım sistemleri uygulaması sonrası araç sistemlerinde ve Avrupa ülkeleri acil yardım sistemleri (EENA) yapısında meydana gelen değişiklikler, trafik ve yol yönetim sistemleri ve altyapılarında da değişiklikler meydana getirecektir. Yeni acil yardım sistemi araç ekipmanları araç mimarisine adapte edilecektir. Bu proje ile birlikte, araç içi acil yardım sistemi uygulamaları operasyonel gereklilikleri ile birlikte tanımlanacaktır. Öte yandan, ülke acil yardım sistemi uygulamaları farklı acil yardım merkezi ve kurtarma servisleri yapılanması dolayısı ile mimari açısından çeşitlenecektir. Yeni Araç Sistemi Uygulamalarına bakan Otomatik ve Manuel Acil Yardım Merkezleri, 112 Acil Yardım merkezi ve Kurtarma Servis Üniteleri; entegre bir çalışma alanında ya da ayrı ayrı binalar ve merkezler olarak yer alabilirler. Bu tezin amacı; araç sistemlerinde oluşturulacak acil yardım sistemini dayanıklı sistem yapılanmasını tanımlamak, araç içi pozisyonunu mekatronik açıdan yorumlamak, ucuzlatma çalışmalarını tanımlamak ve ülkelerin halihazırda kullanmakta oldugu mimarilerini (EENA mimarileri) araç içi acil yardım sistemi uygulamalarının zorunlu hale gelmesi sonucu oluşacak ve çeşitlenecek yeni mimarilerinden hangisinin en optimum alternatif olduğunun seçimini bir filtreleme işlemi yaparak tanımlamaktır. Filtrasyon işlemi içeriği akıllı araç sistemleri ve yol güvenliği sistemleri ve de ülke acil yardım sistemi altyapı bileşenleri olan maliyet modeli analizi ile gerçekleştirilecektir.

Anahtar Kelimeler: Acil Yardım Sistemi, Kurtarma Servisleri, Kaza Bildirimi, Acil Yardım Ünitesi, Acil Yardım Merkezi

CHAPTER 1

INTRODUCTION

According to International Road Traffic and Accident Database (IRTAD) [1], numbers of road fatalities are changing between 3 and 13 in IRTAD member countries in 100000 inhabitants as shown in Figure 1.1. Having these fatality rates cause to take protections for accident and fatalities.

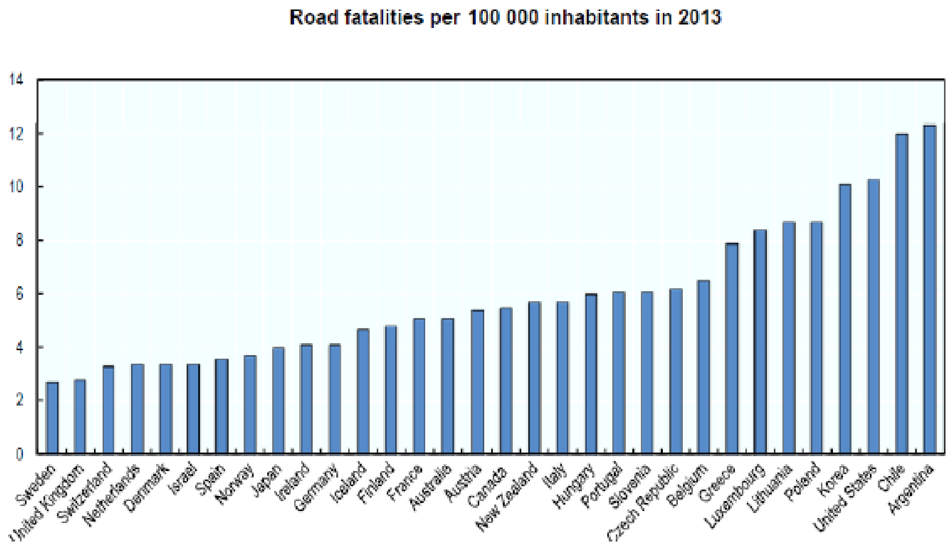

Figure 1.1 Road Fatalities per 100.000 inhabitants' in 2013 in IRTAD Member Countries [1]

Due to the reason explained above, new regulations in the countries are improved. The objective of this thesis is to analyze the next generation emergency notification systems not only in the vehicle structures but also in country infrastructures in Europe with its regulation EU 2015/758 [2]. EU 2015/758 is a European Union regulation which has been published in April, 2015 and its start date of application will be March, 2018. It defines all vehicles will be equipped with emergency call equipment at the end of

March, 2018; while emergency services will be ready for the new public safety answering points system with the start date of October, 2017.

1.1 Literature Review

Literature review of the thesis is searched for three sections in this part. Section-1 is the literature search for eCall structure of the vehicle system which is implemented in terms of the operational requirements and its new structure in this thesis and it has a hypothesis on the issue. Section-2 is the literature search of next-generation eCall systems of the country architectures including infrastructures after eCall equipped vehicle regulations in 2018 which is suggested via its optimal architectures including manual eCall services and automatic eCall services. It is also contended in the hypothesis. Section-3 is the literature search of current EENA architectures' deployments which can have the architecture possibilities for eCall equipped vehicle regulations. Section-2 and Section-3 literature searches are also analyzed not only for technical requirements and technological advancement but also for cost model study including vehicle & road safety and infrastructure.

- Literature Review Section-1:eCall Structure of Vehicle Systems

The eCall structures of the vehicles without any regulation are searched in the literature review, and then it is grouped into 8 sections about their main points. These are;

- Specific Company Systems
- eCall electrical system definition in-vehicle systems
- eCall device and system definitions
- eCall sending signals from the vehicles to the related services
- eCall systems and its application methods in the vehicle systems
- Pre-Crash and Crashing eCall system and Collision Investigations
- Telematic system functionality based on eCall in the vehicle systems
- eCall system cost statuses in-vehicle systems

Specific company systems are the studies of eCall equipped vehicle structures based on its technologies in the companies such as on Star System of General Motor [3], notification systems of Nissan Company vehicles [4] ,WiMax System of Toyota Motor Sales U.S.A Inc.[5], enotify system of IDIADA Automotive Technology [6]. These papers or equal papers in the literature are defining company specific eCall equipped vehicle systems and explaining the vehicle system internal & external boundaries and eCall system external & internal boundaries including eCall components.

In some of the literature surveys, the eCall system is explained as its electrical system approach. For instance, eCall equipped vehicle system is defined about receiver, transmitter, circuit and other related electrical equipment [7-10]. Their content also includes the electrical component technology such as gps receiver, communication devices, data filtrations, vehicle electrical signals.

In the surveys of emergency call system for motor vehicles, the vehicle eCall system type and eCall system flowchart can also be analyzed. For instance, vehicle systems such as radar systems, airbag system, communication system, telematic units are described differently whether the vehicle crash notification system is automatic or not. In addition, the process from vehicle systems to PSAPs are also explained in these type of articles [11-31].

Another point of view in the surveys, the eCall system sending data from the vehicle to the related rescue services such as 112 PSAPs, rescue services including fire station, ambulance station, police station. In these articles [32-40], the eCall system is defined with its protocol, data type, communication data file such as CAN db and etc. Its related vehicle components are defined and the communication flow is mentioned in these studies.

Moreover, the vehicle applications and applicational flowcharts including controlling and monitoring are another case as the research topic [41-57, 197]. Its techniques also include the emergency data communication, its control, alert system and detection systems.

On the other hand, pre-crash and crashing articles also have intersection points with post-crash eCall activities and these study developments also effect eCall study types. The content of collision types, collision predicition, accident severity works, active safety elements, driver behaviors in the accidents are the key points in these type of studies [58-65].

Next, the vehicle telematics unit improvements such as communication of these equipment with eCall devices, eCall related equipment of components are associated with eCall system structure. These are the updates or modifications for the eCall equipped vehicle systems [66-74].

Another point of view about eCall equipped vehicles is its cost status. It is tried to be understood how the ecall system in the vehicle can be adapted to the vehicle having ergonomic structure, good quality and optimal performance [75]. Its studies are component base studies and vehicle system studies. That means the component can have cost reductions & equipment changes and vehicle system can have cost changes & component changes.

As a conclusion of eCall equipped vehicle system surveys, systems in the literature are investigated via the parts above. The difference of this study from the old studies is the eCall device implementation with its internal and external boundaries, eCall device definition with regualtion standards, eCall device explanation with operation requirements including equipment' specifications and its vehicle system specifications. Moreover, up to date power control module of eCall system is described in details and the robustness structure including boundary diagram, p-diagram, RCL are defined for vehicle eCall systems. Next, the cost analyze of intelligent vehicle system via its cost and profits are also detailed in the same analyze. On the other hand, mounting location strategy of eCall control unit in the passenger cars is analyzed as the vehicle application part which includes the filtration process. Its filtration process is detailed via communication sensitivity and cost modeling including electrical connections and electrical interfaces. Communication Policies in the vehicle are supported with respect to the updates for the eCall device which is also a key point for its positioning in the vehicle.

- Literature Review Section-2:Next Generation eCall Systems After eCall Equipped Vehicle Regulations

The eCall infrastructures of the city and countries which consists of eCall equipped vehicles, cellular towers, PSAPs, Rescue Services and Rescue Service Vehicles without any regulation are searched in the literature review, and then it is grouped in 5 sections about the main points. These are;

- Public Safety Answering Point Types
- eCall system Identification
- PSAP Communication Details
- eCall system flowchart
- Emergency Vehicle Overviews

PSAPs are in usage as 112 PSAP at the current status. Its first processes are enabled by text messages, then audio and video data are developed. In addition to them, eCall equipped vehicles will be an obligation, so the PSAP variants will be varied via being eCall PSAPs and 112 PSAP in different types. These system structures are investigated in the magazines with respect to call-in structure, response types, dispatch types, intelligent routing flowcharts, device types [76-82].

Next, eCall systems are analyzed about the emergency call identification processes from the apparatus to PSAPs. Its technology can be different types such as NFC technology etc. These system identification are explained in literature works [83-84].

Moreover, the details of PSAP communications with public communication devices, vehicles, and rescue services are explained with the flowcharts about methodology. Its PSAP network differences such as wireless communication, line-based communication are emphasized. The communication management, method, and apparatus of these services are defined in these type of studies [85-97].

In this point of view, PSAP arrangements, initiators, and track & report types are defined for communication differences. Its database, routing services, and network improvements are presented in the papers [98-111].

Another point of view is the emergency vehicle studies [112-115] about its following path when the accident occurs. Reaching the accident place is an important factor for post-crash items of the vehicle systems.

As a conclusion of eCall infrastructure system surveys, systems in the literature are investigated via the parts above. The difference of this study from the old studies are the infrastructure items especially 112 PSAPs, Manual eCall PSAPs, Auto eCall PSAPs are analyzed for different applicational statuses such as usage of different units, usage of integrated eCall units, usage of integrated PSAP units, usage of eCall and rescue integrated units, usage of eCall, 112 PSAP and rescue services in the same control room/building or etc. Their architectural variants are chosen by the filtration process of the cost modeling and infrastructure possibilities. Infrastructure analyze are based on country case studies which are the search of literature review section-3 and the cost analysis is based on the intelligent vehicle & road safety systems and infrastructure system costs. The cost model approach, its cost & profit cases are also detailed in this analyze.

- Literature Review Section-3:Vehicle Application & Next Generation EENA,Architectures After eCall Equipped Vehicle Regulations

The Literature review section-1 and literature review section-2 are the technical considerations and technological applications; so the references in these literature reviews are grouped with respect to the emphasized topics which means the work package looking approach is applied. In this literature review section-3, the object-oriented looking approach is applied and the few articles about the issue are emphasized case by case. The thesis differences are given in these items exactly.

Mounting Location of eCall device patent of EP-2654025-A1 "Mounting Location of automatic in-vehicle emergency call device" defines the eCall mounting location at the hood side area next to the starter battery. This thesis shows this is the right location or there can be the other optimal possibilities and vice versa. Its analyze & comment is in Part 4.1.7 and its discussion in Chapter-8 and its conclusion is in Chapter-9.

When the article of ITS-2015,IEEE conference-paper [116] "A framework for appraising European Member States' Readiness Level for eCall Deployment" explains the next generation "ERO Independent PSAP" which may be applied as interconnected PSAP type. This thesis shows this is the right command or there can be the other optimal possibilities and vice versa. Its analyze & comment is in the Case Study-1 of Chapter-7.

In addition to this article, the conference papers of ITS-2013, ITST 13th International Conference on ITS Telecommunications and IET Intelligent Transport Systems which are "eCall implementation Roadmap for Finland" [117] and "eCall minimum set of data transmission-results from a field test in Finland" [118] emphasize the eCall related corporations, data process and field tests. This thesis defines the regulations in the issue flowchart. It describes eCall device implementation with its requirements and robustness checks in the vehicle system which is not mentioned in these articles. This thesis enables also the searched country of the articles to make an optimal selection of next Generation eCall system architecture in Case Study-1 of Chapter-7, after the cost model study and architectural filtrations are done in Chapter-5 and Chapter-6.

On the other hand, the study of Harmonised eCall European Pilot [119-120] analyzes the European countries next-generation architectures via its country infrastructure and services. But, the study is an overview and it tries to have an approach to the country situations after eCall equipped vehicle regulations. It gives the architecture possibilities for the European Countries without cost model study and it does not cover the selection criteria. In this thesis, the applied methods are explained in Part 1.4 ‘Methods’ and it covers cost model studies including smart vehicle & road safety which includes the country-specific data. It is explained in Chapter-6 and the result of the Case studies are explained in Chapter-7.

Next, the study of exploratory on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles [121] has a good methodology and it includes potential improvements about the vehicle and transportation systems which are studied in 2005. Its smart vehicle and road safety approach are resemble the thesis. But; the next generation eCall system analyze via vehicle system and infrastructure system does not exist in this study. The next generation European eCall architectures, its next-generation applications are a lack of point in the study. Another lack of a point is the eCall system implementation in the vehicle system is not defined and its only post-crash item properties via socio-economic terms are defined. Moreover, its cost model study is not enough for eCall system investigation. In this thesis, vehicle and infrastructure systems are investigated in cots model approach and the infrastructure variants are explained via its applications such as eCall, 122 PSAP and Rescue service applicational definitions. Moreover, the eCall equipment in the vehicle system is defined by its operational requirements including the robustness structure which means the system boundaries, p-diagram and RCL.

Moreover, the report of Intelligent Transportation Systems Benefit & Costs [122] investigates the next generation transportation systems based on traffic management and its details are mentioned as the statistics in the released year period. Its comment is mainly about the transportation term comparisons via technological and infrastructural cases. On the other hand, the next generation 112 and 911 system reports of the emergency management reports [123-125] define the analyze of the PSAPs only. In this thesis, eCall system is defined not only for vehicle systems but also for country infrastructures including not only PSAPs but also rescue services and the case studies based on cost model approaches are resulted in Chapter-7.

1.2 Objective of the Thesis

The aim of this thesis is to investigate and to give a comment about the next generation of emergency call systems in EENA (European Emergency Number Association) architectures which is applied after eCall equipped vehicle regulations in 2018. The main reasons of analyze are;

- To decide the optimal next generation EENA architectures from its alternatives,
- The definition of new eCall equipment and system with its robustness process in the vehicle structures which will be released in the vehicle systems as an obligation after its regulations.
- The definition of the mounting location of new eCall-ECU (eCall control unit) in the vehicle structure which will be released in the vehicle systems as an obligation after its regulations.
- The explanation of filtration process of possible mounting locations of next-generation structures in the vehicle architectures. The process is detailed via communication sensitivity and cost modeling including electrical connections and electrical interfaces. Communication Policies in the vehicle are supported with respect to the updates for the eCall device which is also a key point for its positioning in the vehicle.
- The description of eCall emergency service variants whether Manual eCall PSAPs and/or Auto eCall PSAPs are adapted to the 112 PSAP or Rescue Service Stations; or these units are created as different services.
- The explanation of filtration process of possible next generation structures of current EENA,architectures. The process is detailed via cost modeling including smart vehicle and road safety systems.

The recession in Europe in 2008 cause to take the precautions about the public expenses and deficits [126]. It means to check the possible unnecessary costs in the systems. Next Generation PSAPs via architectures and cost models are deeply analyzed due to this reason in this article.

The focus of the paper is the next generation emergency call systems. ECall systems in the current status are associated with the public emergency cases which are enabled by public communication devices. After the eCall equipped vehicle regulations [2], emergency cases will be enabled by not only public communication devices but also eCall equipped vehicle devices. These devices can be manual eCall devices and automatic eCall devices. According to their types, eCall PSAP types will also be varied.

The socio-economic impact of the study is defined with the items below [121]:

- Intelligent vehicle and Road Safety Systems Approvals are supported.
- ECall and Transportation Policies are supported with respect to their updates.
- Regulations about the vehicles, traffic management and emergency Call systems are supported.

The main focus in the analyze is the eCall system in the vehicle and next-generation architecture selection of EENA,models which are described in Part 4.2.2 about the current structures. Its next-generation architectures will be applied in European Union Countries after eCall equipped vehicle regulations in 2018.

1.3 Hypothesis

The emergency call systems via its country architectures and its vehicle system development are implemented and its deployment of eCall equipped vehicle regulations in 2018 are analyzed in details in this thesis. The hypothesis of this work can be summarized with the items below.

- New vehicle system structure including eCall equipment is implemented and its operational requirements are suggested with Robustness Structure of failure mode effect analyze.
- Mounting Location Strategy of Emergency Call Control Unit in Passenger Cars is released via its optimal option.
- The European country emergency call system architectures after eCall equipped vehicle regulations are suggested.
- The whole change points after eCall equipped vehicle regulations of Current European Emergency Number Association Architectures are described and its next-generation alternatives are suggested to be an optimal system with respect to cost model and technology.

The cost model approach including vehicle system, road safety and infrastructural system is advised to decide the optimal architecture selection for the current emergency call systems after eCall equipped vehicle regulations.

1.4 Structure of the Thesis

The thesis "Next Generation Emergency Notification System: Model Development Based On the Optimal Architecture Selection of European Countries and In-Vehicle eCall Systems Implementation" consists of nine main parts and it is analyzed within 5 parts in the 6 sigma DMAIC concept as it is shown in Figure 1.2. Six Sigma is a tool of Industry to solve the problems and produce the new design concepts [127]. Its new concept creation is enabled by the DCOV-R tool and the problem-solving approach is enabled by DMAIC-R concept. When DCOV-R means the Define, Characterize, Optimize, Verify, Repeatability; DMAIC-R is the Definition, Measurement, Analyze, Improve, Control and Repeatability. "-R"; Repeatability is applied to the systems if it is required which means it can be optional section.

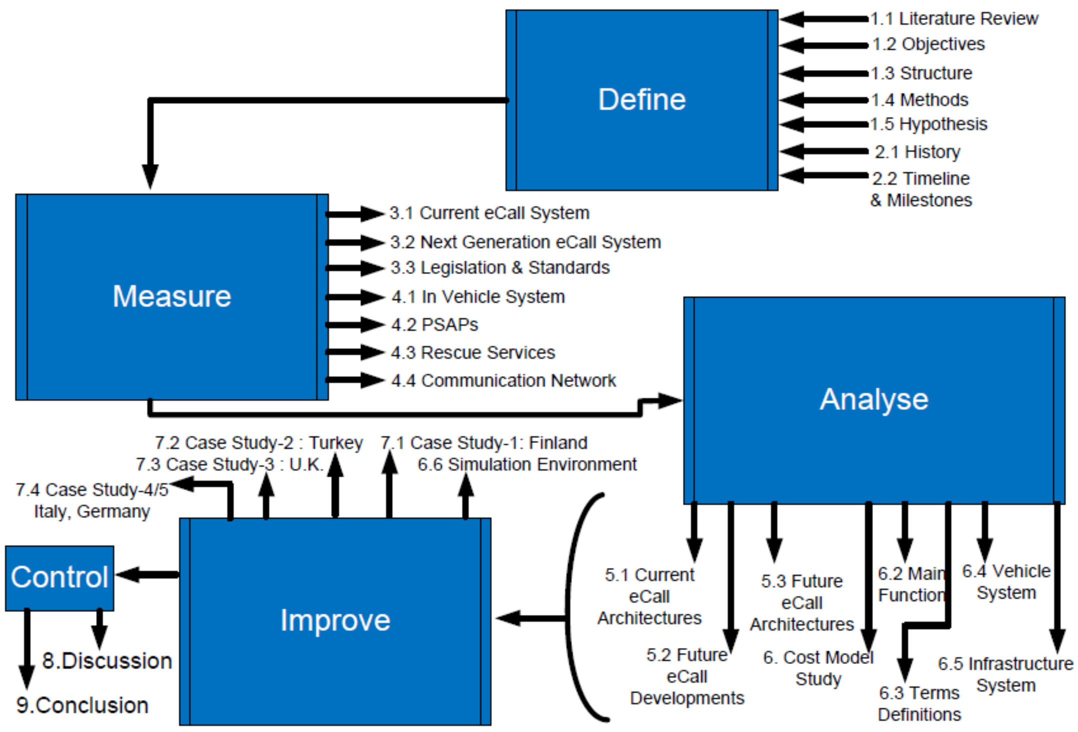

Figure 1.2 Structure of Thesis

As it is shown in Figure 1.2, The first two chapters which are Chapter 1 and Chapter 2 includes the history, literature review, structure and methodology are the Definition part of the –DMAIC- process. Chapter 3 and Chapter 4 which are the eCall system definitions for the current & next generation statuses and its system & vehicle infrastructure details are the Measure part of 6 sigma concept. 'Measure' means the data and information of defined topic in details. Next, Analyze is the part of improvements, developments, calculations and validations of the defined topic. In this thesis, eCall system architecture and developments are investigated in Chapter 5 and the filtration process of architectures with cost model study including intelligent vehicle and road safety with infrastructure system are studied in Chapter 6. Then, the simulation environment of cost model study in Part 6.6 and the case studies of the countries such as Finland, Turkey, United Kingdom, Italy and Germany are analyzed in Chapter-7 as the Improvement part of 6 Sigma concept. Improvement is the part including results, comparisons and solving of root causes. Finally, the Control process of DMAIC concept includes discussions which is Chapter 8 and conclusions which is Chapter 9 and the repeatable actions if it is necessary. Repeatable actions are the process of the problematic conditions if they are repeating more than one time. The thesis gives a clear result without any reputable cases; so it is not related to the repeatable action part.

When these structural parts are reviewed via its content, it can be explained as it is shown in Figure 1.3.

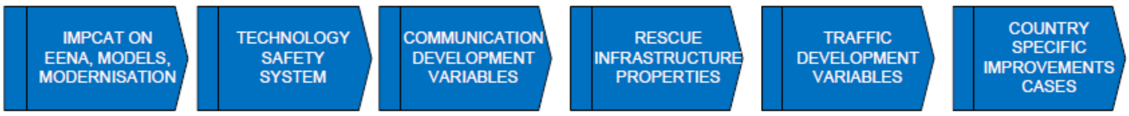

Figure 1.3 Content of Thesis Structure

As it is also emphasized in DMAIC content of Figure 1.2, Figure 1.3 means the eCall architectures are analyzed via safety systems including vehicle and road safety which means the technological part. Next, the communication process after eCall equipped vehicles is varied due to new two eCall PSAPs. These PSAPs can affect the rescue infrastructure properties whether they are integrated with each other or not. All these improvements will make an analyze in the traffic management such as traffic congestion, traffic time management, traffic operation management and traffic accident costs. These whole content are worked in details for the country infrastructures and optimal alternatives are concluded with the case studies of EENA,Architectures.

1.5 Methods

The methods of next-generation emergency call system after the eCall equipped vehicle regulations can be described in four sections :

- Standards and Regulations
- Robustness Working Principle of eCall Equipped Vehicles

- Filtration Process of Mounting Location Strategy of Emergency Call Control Unit in Passenger Cars
- Architecture Selection Criteria’s of Infrastructures
- Cost Model Evaluation Types

First of All, Standards and Regulations are deeply analyzed in the section, ‘Emergency Call Systems via Regulations’ which is the content of Part 3.3. The main case about the issue is created by the regulation of European Union 2015/758 [2]. The other explained legislations are the standards which enable the system works properly such as end to end conformance tests (Regulations R14, R15, R16 and R17 in Figure 3.4), data registry procedures, eCall data sets, protocol requirements, digital communication standards. When R9 in Figure 3.4 is the ECall data transfer regulation, R5 and R6 are the eCall network access device regulations. These regulations in Figure 3.4 define the whole system tests. The infrastructure needs to be released after passing them. Architecture selection in the third section is enabled by summarizing the possibilities in Table 5.1, Table 5.2, Table 5.3, Table 5.4 and Table 5.5. These tables are the combination of basic eCall system structures and new generation eCall receiving’s types.

Secondly, eCall equipped vehicle systems are set up with the robustness structure including working principle of Figure 1.4.

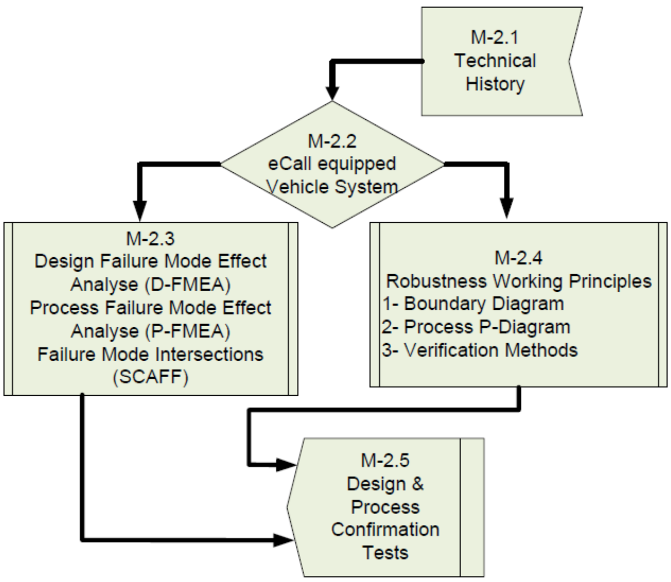

Figure 1.4 Robustness Working Principle of eCall equipped Vehicles

As it is shown in Figure 1.4, Robustness Working Principle of eCall equipped vehicles can be applied to 5 main parts which are explained as M-2.1 to M.2-5 (Method-2

Principle-1 to Method-2 Principle-5). M-2.1 is the technical history and it is defined in Part 1.1 in Literature review section-1. M-2.2 is the eCall system in the vehicle structure and its definition is explained between Part 4.1.1 and Part 4.1.3. Next, the boundary diagram (M-2.4 item-1) of eCall device in the vehicle system and its vehicle system adaptation are described in Part 4.1.4 and Part 4.1.5. Boundary diagram explains the eCall system boundaries including internal equipment details and external vehicle system relation when P-Diagram enables to understand which vehicle system interactions it has (M-2.4 item-2). Moreover, Verification methods are the test sequences which enables the ideal output functions if the system noises & problems occur (M-2.4 item-3 & M-2.5). It is explained in Part 4.1.6. Without FMEA study which is M-2.3 in Figure 1.4, the whole robustness working structure of eCall equipped vehicle system is released in Thesis Content. M-2.3 (FMEA studies) needs to be created and released by Automotive OEMs and by Tier-1 suppliers of eCall systems; so it is not processed in this study. This working principle enables the systems such as eCall system in the vehicle to work properly with fewer problems and without time loose.

<u>Thirdly,</u> mounting location of eCall control unit in passenger cars is investigated by communication sensitivity and cost of electrical equipment. Cost status is created by the electrical path differences between :

- eCall control unit and vehicle telematic control unit
- eCall control unit and communication & positioning antenna

  On the other hand, communication sensitivity is analyzed by;
- Electrical Equipment differences of mounting locations (Sensitivity Factor-1)
- Electrical wiring differences of mounting locations (Sensitivity Factor-2)
- Communication Network Requirements with respect to eCall Regulations (Sensitivity Factor-3)
- eCall Signal Amplitudes (Sensitivity Factor-4)
- eCall control unit design concept via its antennas (Sensitivity Factor-5)

<u>Fourthly,</u> architecture selections of country-infrastructures are enabled by three factors:

- Current EENA Architectures
- New eCall Receiving Types
- Vehicle eCall Equipment type whether being an automatic or manual device.

Current EENA architectures which are in usage in the European Countries at the current status are summarized in Figure 5.1 and described in the Chapter 5 “ECall System Architectures”.

New Ecall receiving types are Manual eCall PSAP-calls and Automatic eCall PSAP-calls. They are explained in Part 5.2 and the new architecture variants via new eCall receiving’s are analyzed in the Tables between Table 5.1 and Table 5.5 in Part 5.3. Vehicle eCall equipment can be manual device and automatic device. The equipment type effect on the process is analyzed in details with the flowchart in Figure 5.7, Figure 5.19 and Figure 5.24.

Fifthly, the cost model types can be processed as subjective or objective evaluation methods. The subjective method defines the system according to “willingness to pay” approach includes the surveys from the internal and external customers which are not related to this paper. Normally, The objective method includes the cost of damage, cost of avoidance and market data divergence analyze. In this paper, cost of damage and divergence analyze are calculated when collision avoidance cost is not included due to being a post-crash item. The cost model evaluations can be produced in 6 types as below [121]:

- Cost-Effectiveness Analyze
- Financial Analyze
- Break-Even Analyze
- Business Case Calculations
- Multi-criteria Analyze
- Benefit to Cost Ratio Analyze

Cost-effectiveness shows the cost alternatives when financial analyze emphasize the impacts of activities. Breakeven analyze defines the breakeven points. In addition, business case calculation defines the system with respect to benefit and risk costs when multi-criteria analysis shows the importance of social objectives more than market values. In this paper, the benefit to cost analysis in the system architectures is investigated. This evaluation includes benefits of the next-generation system and the potential cost of technology and measurements. This study is related to benefit and system cost; so it is analyzed with Benefit to Cost Ratio. The other types of evaluation methods are also the financial analyzes based on activity impacts, cost alternatives, break-even points, cost risks and social objectives.

Moreover, the Cost model is analyzed in two sections which are intelligent vehicle safety system and system cost. Intelligent vehicle safety system is analyzed with good and passenger transportation functions. It does not totally speed function but there are some parts' calculations include speed function such as time cost and vehicle operating cost. In this point of view, other important methods are fuel consumption and emission costs. Fuel consumption calculations are based on fuel consumption rates, are analyzed according to Lam Formula [128-129]. On the other hand, emission calculations are based on emission factors [130-132]**.** When intelligent vehicle-equipment rates are defined by ACEA [133], accident cost unit rates are described by EU [1]. Taking these approaches into consideration, all details about intelligent vehicle safety system is analyzed in Part 6.4. Another part of cost model is system cost. It is defined with two parts which are an investment and operating costs. Investment cost is about eCall equipment costs of vehicles when the operating cost defines the infrastructural-system cost. Its cost includes PSAP costs, training costs and number of PSAPs. Numbers of PSAPs are calculated by NENA, EENA standards and population rates [134-136].

As a conclusion of methods and approaches, several factors and calculation methods are defined. These methods need to be fitted with CEN (European Committee for Standardization), ETSI (European Telecommunication Standards), ISO (International Standards for Organizations) and EN (European Standards) in applications. The standards are explained in Part 3.3 in details.

CHAPTER 2

GENERAL INFORMATION

Emergency call system developments in the history are nearly starting from 1950 and its structural improvements are varied in the continents. Today's milestones include the emergency call system with eCall equipped vehicles due to an increase in road fatalities and accidents. Transportation is a key point in the socio-economies & technological advancements and its problems such as congestion, a harmful effect to the environment, public health, road accidents are tried to be reduced [121]. In this point of view, the integration of emergency call system improvements and reduction of the transportation problems creates a new concept as emergency call system not only for public issues but also for vehicle accidents. The legislation is modified to make an obligation of eCall equipped vehicles and updates of safety answering points. The stages of emergency callings structures have passed through in its distinguished past are outlined in Part 2.1 and its timeline & milestones of today's technology are emphasized in Part 2.2.

2.1 History

Emergency service notification and dispatch operations have the genesis of the recommendation of National Association Fire Chiefs in 1957 for a single number to report the fire [137]. In 1968, the United States 911 number is established as emergency notification number nationwide. Its European establishment to integrate all Europe in a single 112 number is enabled by the European Council in 1991.

The single European emergency number 112 was adopted by Council decision in July, 1991. Its aim is to provide citizens of EU to call the emergency services by using the same number in Europe. It was obligated at the end of 2008 in all EU members [138].

The rescue services can be different when the 112 is called by the communication devices. For instance, Germany is using fire station as 112 PSAP when Italy is using police station as 112 PSAP. Some other countries are also using 112 PSAP services as a different unit. Then, the traffic accidents are shown as one of the major causes of the deaths and injuries [139]. When the traffic accident occurs, vehicle passengers and drivers may not reach the communication devices and may not call using mobile phones. Next, European Commision adopts the recommendation on 8 September 2011 that eCall is placed in 2015 [140]. The Commision adopted the specifications for the PSAPs under Intelligent Transport Systems Directive with 2010/40/EC4 [139]. Due to the developments of emergency call cases starting from 1991 to 2015 defines the improvements of the preparation in eCall equipped vehicle regulations. In the legislation of EU-2015/758 which is published in April, 2015 is defined that the new PSAPs' structures including 112 PSAPs and eCall PSAPs are ready on 1st October 2017 when the eCall equipped vehicles which are passenger cars and light duty vehicles are ready to use on 31 March 2018. Its timeline and milestone structure is described in the next section in Part 2.2.

2.2 Timeline & Milestones

The emergency call systems are modified or updated to have new eCall receiving types such as Manual eCall receivings, Automatic eCall receivings. The current 112 PSAP systems in EENA Current Architectures, current transportation systems, and current vehicle systems will have an improvement about eCall structures which creates eCall equipped vehicles, smart transportation systems and three PSAP types such as 112 PSAPs, Manual eCall PSAPs and Auto eCall PSAPs with different applicational structures. These improvements are started to be delegated in 2012 and its decisions & implementations continue in these time periods until 2018. Its timeline & milestone content is defined as it is shown in Figure 2.1 below.

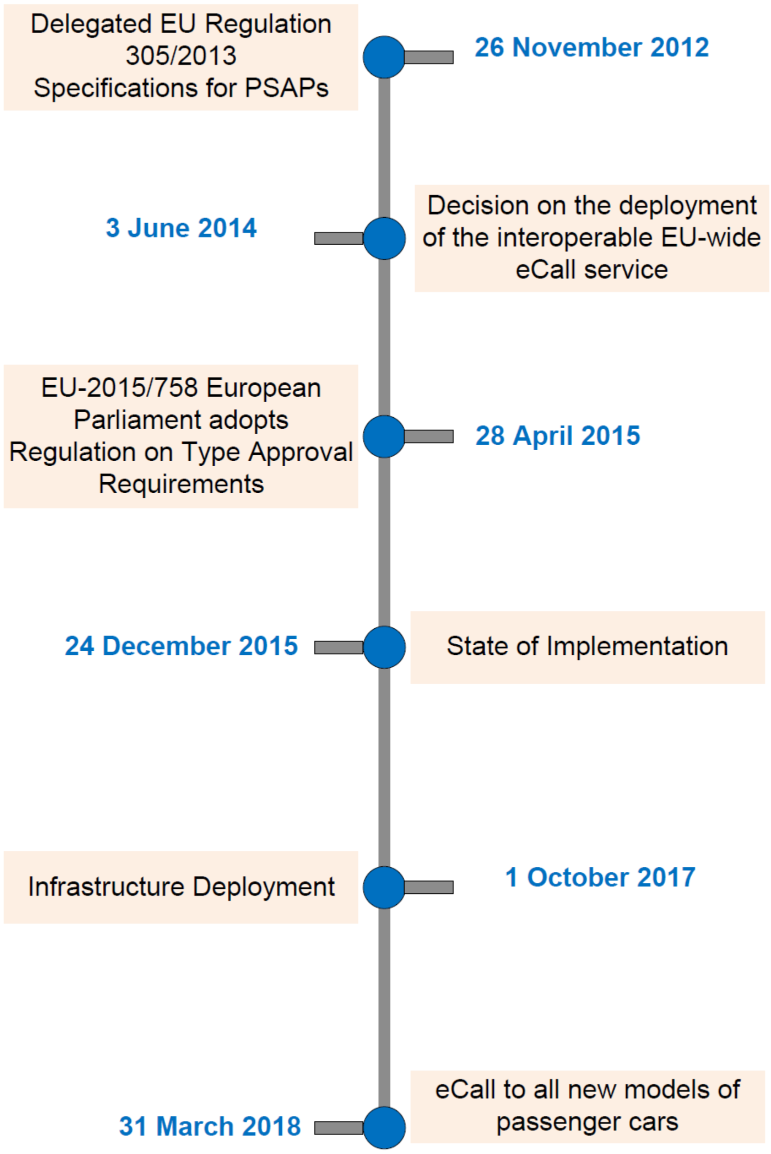

Figure 2.1 eCall Timeline & Milestones

As it is shown in Figure 2.1, specifications of PSAPs are delegated on 26 November 2012. Its content is about the harmonized provision of interoperable EU-wide Callings. Then, the European Parliament and European Council adopted the decision of interoperable EU-wide eCall service applications on 3 June 2014. Moreover, eCall type-approval requirements are regulated by European Parliament on 28 April 2015. Lastly, the member states explain their planning about the eCall implementations in December, 2015. After these periods, infrastructure deployments which includes eCall PSAPs readiness is applied on 1st October 2017, and then the new models of passenger cars including also light commercial vehicles are equipped with eCall systems at the end of March, 2018.

CHAPTER 3

EMERGENCY CALL SYSTEM

Emergency call service is the unit to help the callers about the rescue situations. Large communities in the world are served by these services and the attention to the emergency call systems are increasing [141]. The services are the interaction between a caller and an operator in the answering points and the emergency service responsible person identifies the rescue problem via its location, problem types. Improving the communication between the public and the emergency services is a key objective within the Related Unions and governments' policy recommendations. The Unions and the governments in the light of recent years and initiatives try to improve both the emergency and non-emergency services [142].

Emergency call system structure is sought to enhance the quality and reinforce the country dimension of eCall provide by expanding eCall management system with the combination types of PSAPs, rescue services, vehicle eCall PSAPs in different architectures via the country database.

Emergency call system service stakeholders consist of in-vehicle equipment providers, mobile network operators, telecommunication national regulators, authorities such as European, National, Regional, Public Safety Answering Point, Emergency Response Organization such as Fire, Police, Ambulance, third party service providers in case of telematic service provider eCalls, citizens and road operators [126].

When the European improvements on the issue are analyzed at the current statuses, ECall equipped vehicle regulation is targeted at higher service quality and their service network & staff in all EU Member States of the European Union are expanded with new eCall PSAPs such as Manual eCall PSAP, Auto eCall PSAP. Manual eCall PSAP is the service for manually triggered emergency calls when Auto eCall PSAP is the service of emergency calls which are triggered automatically.

When the European Automotive Industry is analyzed on the issue with this regulation, the new safety equipment adaptation is required based on post-crash activities. The new vehicle architectures are created including emergency call system equipment such as eCall measurement unit, its control unit, vehicle preparation and functionality units.

Taking the improvements of both infrastructure and automotive industry into consideration, the eCall system current status is defined in Part 3.1. Next, the improvements and future statuses are described in Part 3.2, and then the legislation and standards are expanded in Part 3.3.

3.1 The Current Structure of Whole Generic eCall System

The current status of emergency call system as a generic scenario without any architecture specification is summarized in Figure 3.1. In Figure 3.1, unit-11 explains the communication device (11) such as mobile phone which enables the person to call the emergency services when there is an emergency case. Unite-4 is the cellular tower (4) that enables the communication from the communication device to a 112 PSAP. Next, Unite-6 is the communication network (6) carries the emergency data to the PSAP which comes from a cellular tower. Moreover, unit-7 is a most appropriate 112 PSAP (7) which responses the emergency callings of any public issue to inform the rescue services. Moreover, Unit-14 is the ambulance station (14) and unit-15 is the police station (15) when Unit-16 is the Fire station (16). Unit-10 is the rescue service vehicles (10) which reach the accident places such as police vehicles, ambulance vehicles, fire vehicles if the emergency case occurs.

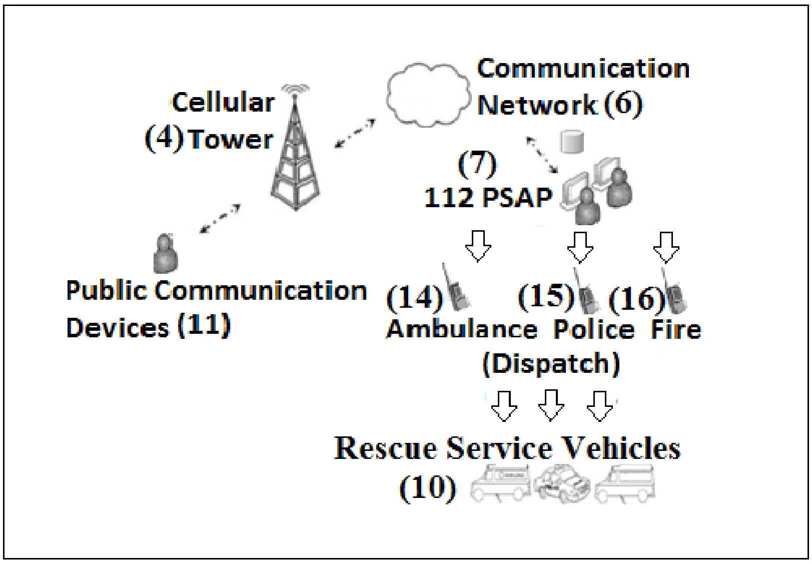

Figure 3.1 General Public Communication Structure [143]

In Figure 3.1, the emergency call for a public issue is enabled by mobile phone or another communication device (11) while the emergency case occurs. The emergency case data is forwarded to the cellular tower network to be processed in the cellular tower. The signal power of emergency case data and cellular tower capacities decide the choice of the cellular tower (4) in cellular tower network. After the decision process, cellular tower receives the data, processes it and sends to the communication network. Communication network (6) defines the emergency case-data and decides the public safety answering point to transfer it. There exist most appropriate 112 PSAP (7) at the current status. It takes the signals such as text-message, audio data, or video data; and then processes it. 112 PSAP in this system gives responses to all emergency callings and forward it to the related rescue station(s) (14 and/or 15 and/or 16). Emergency case related rescue station(s) defines the situation and processes its data. Then, it is dispatched to the related rescue service vehicles (10). Finally, rescue service vehicle(s) reaches the emergency case place.

Its generic structure changes after eCall equipped vehicle regulations will be defined in the next section Part 3.2.

3.2 The Whole Generic eCall Structure After eCall Equipped Vehicle Regulations

With EU Regulation 2015/758 which will be applied in 2018, All Vehicles in EU are equipped with emergency call equipment [2]. Up-to-date Generation ECall and 112 systems will be modified with respect to PSAP types and ECall Receiving types of Rescue Services. Figure 3.2 shows the updated accident case-study with a new emergency call infrastructure and its vehicle behavior. It shows the general scenario of emergency call case with updated PSAP types (7, 8 and 9).

Some of unit-numbers (4, 6, 7, 10, 11, 14, 15, 16) are defined in Figure 3.1. In addition to these units, in Figure 3.2; the global positioning system satellite is described with (1), the vehicle is defined as (2), emergency call device in the vehicle is defined as (3), tree which is a crashing point of the vehicle in the accident scenario is defined as (5), new units due to new emergency call receiving structure are marked as (8) and (9). Unit-8 is the manual eCall PSAP which gives a response to the accident of the vehicle including manual eCall unit when Unit-9 is the automatic eCall PSAP which gives a response to the accident of the vehicle including automatic eCall unit.

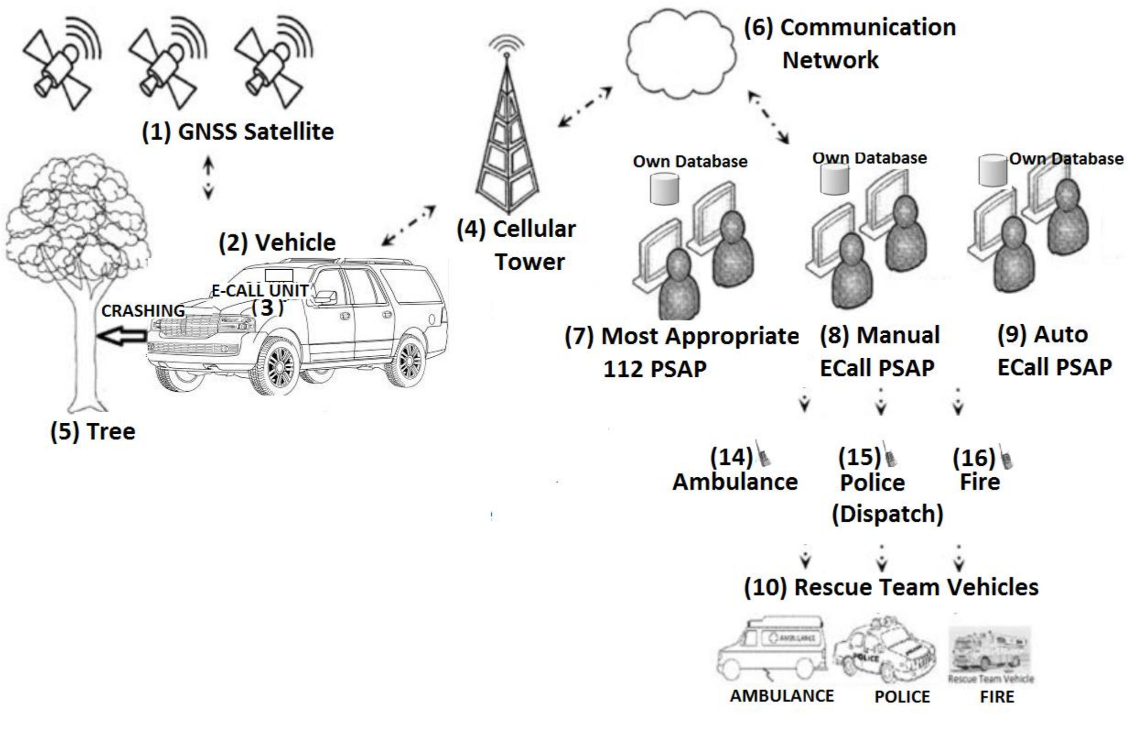

Figure 3.2 Generic ECall Structure of New Crash Notification System

It can be assumed in Figure 3.2 that the vehicle (2) crashes the tree and it needs urgent help. Emergency call device (3) is activated manually or automatically. Then, the vehicle emergency call device sends at least the minimum data set to the cellular tower (4). Communication with public safety answering points (7 and/or 8 and/or 9) is provided via a communication network (6). PSAP variants can be three types as it is shown in Figure 3.3(below-figure). Variant-1 in Figure 3.2 is the most appropriate 112-

PSAP (7) and it is used for all 112 and emergency cases of public issues. The variant-2 (8) is Manuel ECall PSAP and the variant-3 (9) is Automatic ECall PSAP which are newcomer PSAP services with the new regulations. They are not working on other public issues. These are working for only accidents of ECall Equipped-Vehicles. Manuel ECall PSAP is the service provider for manually triggered emergency call units when Automatic ECall PSAP is for automatically-triggered emergency calls. According to Country Infrastructures, usage of 3 kinds of PSAP will be designed. ECall condition needs at least one of Private ECall PSAP (8 or 9) or expanded 112 PSAP for this new system. It depends on country infrastructure [143]. Then, PSAP provides the accident information to the required rescue service (8). Next, the rescue services can be police services, ambulance services or fire services. In this case; there can be a multitude of options whether enabling one, two or all rescue services for the accidents. The correlations according to PSAP services and ECall receiving's of Rescue Services are summarized in Figure 3.3. The information in Figure 3.3 is the general variant information about PSAPs and EROs without specific infrastructure systems. Next steps will be explained in Chapter 5.

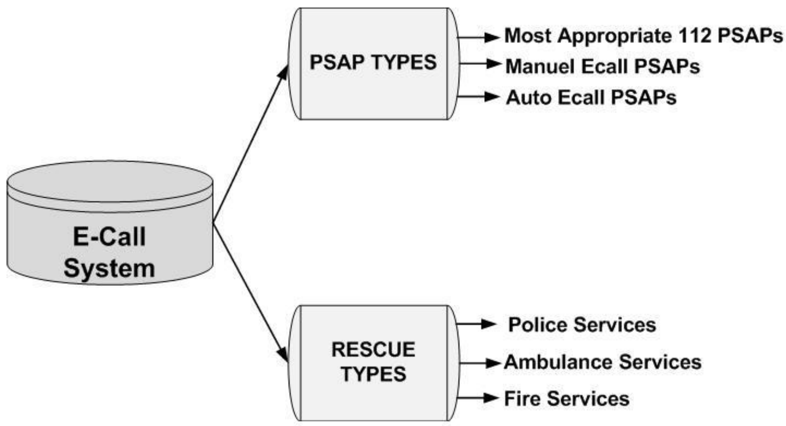

Figure 3.3 Services in Next Generation Ecall System

As it is described in Figure 3.3, three types of PSAP can be used with EROs (Emergency Response Organizations) which is expressed as ecall receiving types and rescue types. In this manner, working principle in Figure 3.4 includes modifications at P8 and P9. In P8, PSAP type is not only 112 PSAP but also eCall PSAPs. After P7 is completed, data is sent to 112 PSAP and/or eCall PSAPs. Ecall data set can be sent to (i) only most appropriate 112 PSAPs; (ii) 112 PSAPs and Manuel eCall PSAPs; (iii)

112 PSAPs and Automatic ECall PSAPs; (iv) all 3 PSAPs. It depends on Country Infrastructures. Next, P9 provides the communication network with Rescue services. Ecall receiving' and dispatch-processes can be varied via system model of the country infrastructures. It is explained with Part 3.2 and Part 5.2 in ECall receiving types and with Part 5.3 in Functional definitions, Technical descriptions & RDVs.

3.3 Legislation and Standards

According to European Union Regulation EU-2015/758 [**2**], eCall equipped vehicles are started to use in March, 2018 when the new PSAP structure with vehicle eCall receivings is being ready in October, 2017. The eCall type approvals [195] are applied to the vehicle and country infrastructures. The main standard and regulations are emphasized in Figure 3.4 with its process flow, then the Figure 3.5 gives a total scenario of the standards and regulations on the infrastructures. After these standards and process summaries, the table of content for standards are resulted in Table 3.1.

The process flowchart including the regulations defines the emergency call case of the whole eCall system structure. It includes European Union legislation and all processes with 17 regulations. These regulations include the communication standards, data registration standards, tests procedures and data service rules via European eCall operating.

When the road-accident occurs in Figure 3.4, eCall activation (P1) is enabled automatically or manually. If the eCall unit is triggered manually, it is needed to be activated by driver or passengers. In addition, the eCall unit can be activated without any external input if it is triggered automatically. The activation process is provided when the ignition and eCall wake-up signals come to eCall unit by the vehicle control module. After these signals are transmitted to the eCall device which has two main parts as eCall measurement unit and control unit, the supply voltage is provided by starter battery of the vehicle. This is the first step of emergency notification (P2) process flow. This is to say, it is the vehicle process side of all-flow needs to be fitted with regulation R1 which is ISO/EN 24978 [144] means data registration process.

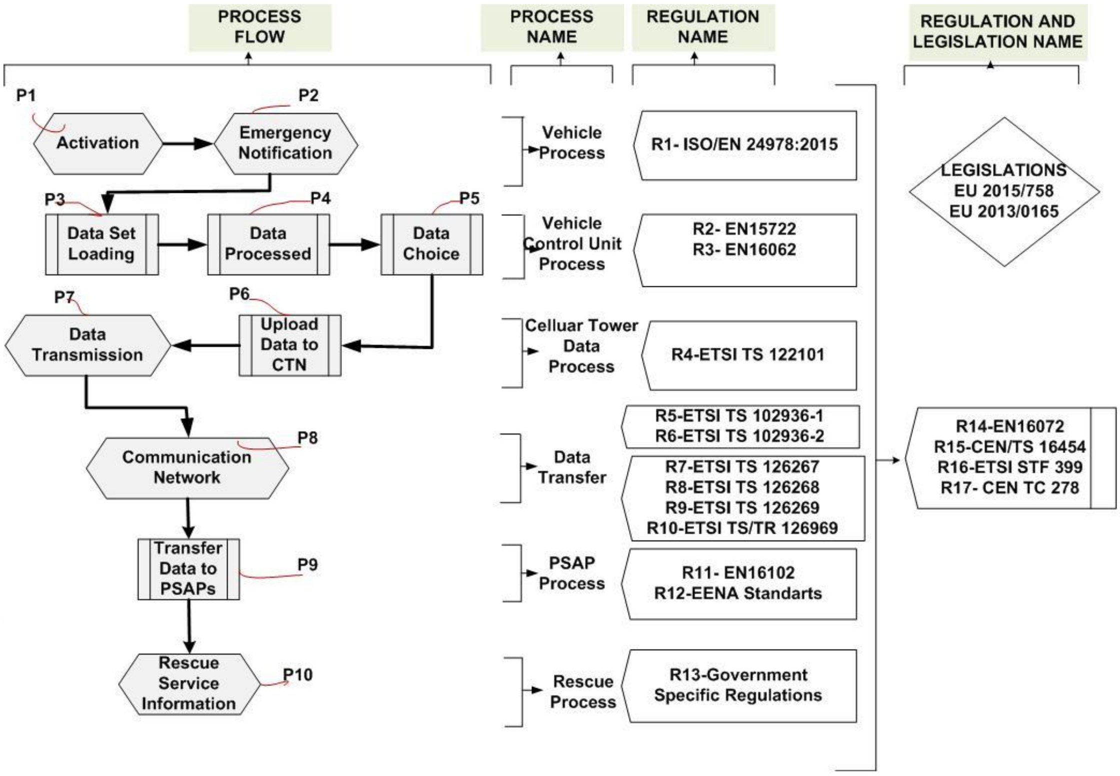

Figure 3.4 Emergency Case Process Flowchart with Regulations

Next, vehicle data set about crash notification is loaded in P3 in Figure 3.4. Data process continues with the boost processor which produces a different type of voltages such as 3V, 4V, 5V when the vehicle location is received by internal GNSS module and then, the cellular connection is active to be used in GSM module in the eCall control unit. By the way, led’s and buttons are ready for usage. When the boost processor sends the signals to LED’s and buttons, the rechargeable battery is used to protect the power losses in the system. At the same time, airbag signal, motion data and car crashing input are sent to main-processor of eCall control-unit. By the way, vehicle positioning data is enabled by internal GNSS antenna inside the eCall unit when the cellular connection is provided with cellular antenna including cellular-card infrastructure. In the mean time, eCall unit is ready in progress. At this point, the eCall unit software process (P4) needs to be reviewed. The software defines at least 5 main parts which are application data layer, application framework, software library, hardware abstraction layer, android/IOS process runtime and Linux-kernel parts. Before defining these points, their regulations are emphasized. Regulation R2 which is EN-15722 [145] defines the eCall minimum data set including location data, accident severity, and vehicle identity number. These data sets are processed inside of eCall control unit with the software protocol rules defined in the regulation-R3 which is EN-16062 [146]. Data sets which will be forwarded to the cellular tower are processed in its software by application and application framework thanks to Android/IOS main-processor. Linux-kernel part of software describes the vehicle data based on pre-crash and crashing information. Moreover, the library has the parts such as surface managers and media frameworks. In addition to this part of the software, OEM specific applications are activated in its own framework. After the data process with this software status, data sets which will be sent to cellular tower are controlled by measurement unit including its own codes. That is the data choice (P5) process. All data in P4 and P5 are computer-readable data. Moreover, transmitted data sets are sent to the cellular tower (P6) and its network. This transmission enables the data to fit the regulation R4 (ETSI TS 122101) [147] called as service rules of the digital cellular telecommunication system. Strongest data signals of emergency call are recorded in more than one cellular tower in cellular tower network (CTN) with the duration of 30 seconds [148]. Cellular towers have the edge between each other's so the strongest signal of emergency call data is processed without any problem. Data is transferred to the cellular towers according to their capacities with the total amount of call duration and call events. Then, the data is forwarded to a communication network (P8). ECall services implement the two main statements which are interoperability and harmonization. Interoperability is an operational solution to provide the required services when there is an accident in the country. Nevertheless, harmonization in the system enables the vehicle to have traveling to different countries with the same emergency service structure which defines the harmonized-way approach. Communication network needs to be fitted by the regulations via protocol specifications and test suites. Protocol details are regulated by regulation-R5 (ETSI TS 102936-1) [149] and test suites defined by regulation-R6 (ETSI TS 102936-2) [150]. These are the regulations of network access devices. Moreover, eCall data needs to be checked with respect to regulations R7 (ETSI TS 126267) [151], R8 (ETSI TS 126268) [152] and R9 (ETSI TS 126269) [153]. R7 is the general description of eCall data & its transfer when R8 defines the eCall data code-requirements. Additionally, regulation-R9 is the tests of eCall data conformance. Taking these eCall regulations into consideration, characterization of the data is not defined yet. This definition is created by regulation-R9. After the signals are active about these regulation properties, they can be transferred to PSAPs (P9). Public safety answering points (PSAPs) whether it is most appropriate 112 PSAPs or eCall PSAPs need to be in the EENA standards-R12 [154]. In addition, regulation-R11 (EN16102) [155] which is third party operating requirements explain the required-properties for the third party services which can be generally used for new eCall answering points. PSAPs which are the service provider organizations include the equipments such as infrastructures; networks have the capability of receiving's the accident data and forward them to the related services. PSAP types are analyzed in details in the Part 4.2.5 "Details of PSAP Infrastructures in EENA Architectures" and Part 4.2.6 "Details of PSAP Infrastructures after eCall equipped Vehicle Regulations in 2018". According to PSAP types, PSAP worker functionalities are changing. Operators can be only call-taker or not only call-taker but also dispatcher as it will be explained in Part 4.2 and Part 4.3. After the data is processed as data entity in public safety answering points, EROs are informed to reach the accident places. This is the whole story of one of accident case with its regulations. On the other hand, the whole system requirements on the regulations are not defined yet. Regulation-R14 (EN 16072) [156] is the pan European eCall operating requirements need to be analyzed for all system structure when regulation-R15 (CEN/TS 16454) [157] is the eCall end to end conformance testing. Moreover, end to end conformance tests are also analyzed by the regulations R16 (ETSI STF399) [158] and R17 (CEN TC 278) [159].

The process flow in Figure 3.4 and its explanations above gives a result of scenario as it is shown in Figure 3.5 [196].

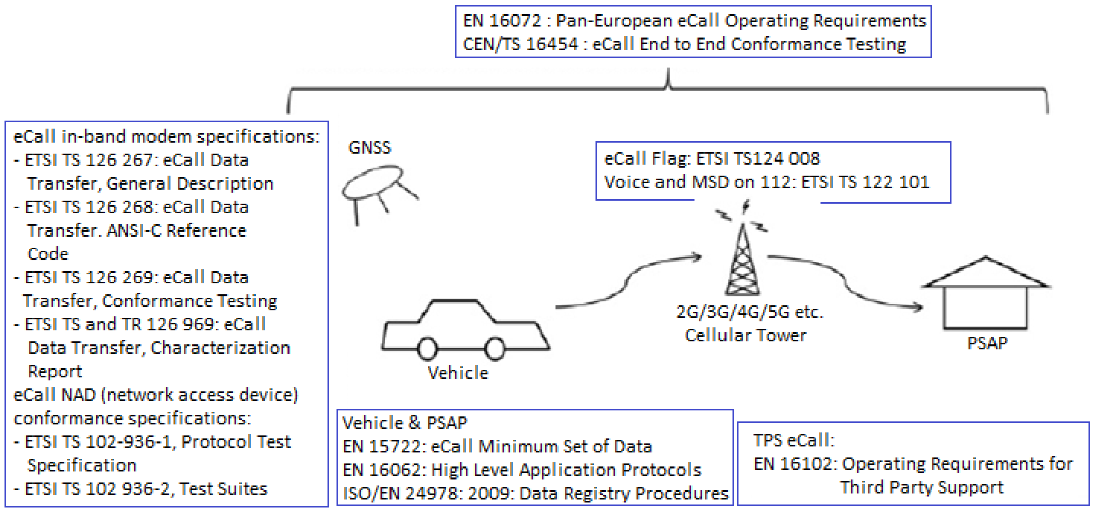

Figure 3.5 Emergency Case Applicational View with Regulations [196]

The standards are separated via its missions in Figure 3.5. It enables Figure 3.4 which is process flow including standards, to be understood with its applicational view.

As a conclusion of legislation and standards, the rules of obligations are explained with CEN (European Committee for Standardization), ETSI (European Telecommunication Standards), ISO (International Standards of Organizations) and EN (European Standards).

CHAPTER 4

ECALL SYSTEM STRUCTURES

Accidents cannot be avoided by Post Crash Equipments [160] such as eCall systems in the vehicles. Nevertheless, faster Emergency Services to reach the accident places and decreasing the accident costs with respect to saving a life can be enabled by new generation crash notification systems. Besides, the communication between the vehicle and public safety answering point (PSAP) and Rescue services exist which are communicated thanks to a cellular tower. In this chapter, eCall system parts such as vehicle systems, cellular tower, PSAP, and rescue service & rescue service vehicles are explained based on new crash notification system after eCall equipped vehicle regulations in 2018. The changes in automotive applications after eCall system adaptation is analyzed in details and the main focus of this chapter will be on the vehicle application side. On the other hand, PSAPs and Rescue Services will be explained via their equipment, personal requirements when the cellular towers are defined via their network statuses.

4.1 In-Vehicle Technology

ECall Unit which is post-crash road safety equipment enables a value-added service for vehicle customers with this aim [121]. Emergency call system specifications are created by procedures of call control, procedures of mobility management in-band modem implementations and procedures of data-set operating requirements. In this Part, the emergency call system and related vehicle systems in the vehicle are investigated in section-1; then, emergency call component hardware details will be explained via its device operating requirements, device hardware functionality and connector details in Section-2. Next, eCall device electrical surrounding in vehicle and PCM (power control module) is analyzed in Section-3. After section-3, robust structure of component which are its internal boundary diagram, p-diagram and robustness checks are analyzed in section-4, in section-5 and in section-6 separately. The internal boundary diagram defines the device internal equipment relations with each other when p-diagram is the process flow of the device. Finally, the robustness checklist shows that the vehicle eCall system can have error states and these error states can be associated with the system noises which are defined in p-diagram; and then error states vs. noise relations are integrated with verification methods to solve the vehicle eCall structure problems systematically.

4.1.1 Vehicle Components: Ecall Unit and Related Vehicle Systems

In this section, the vehicle system is overviewed via the related eCall system components as it is shown in Figure 4.1. Vehicle eCall system overview includes the components such as GNSS Antenna and its splitter, GSM antenna and its splitter, eCall activation signals and eCall working signals in the vehicle. When eCall activation signals in the vehicle are a wake-up signal, vehicle ignition signal, supply voltage (V+) and ground (V-); eCall working signals in the vehicle are Car crashing input, airbag signal, sensor input and vehicle signal.

As it is shown in Figure 4.1, the GPS and GSM signals are also separated to the other telematics units in the vehicle such as navigation, tachograph, PPC (powertrain predictive control) and vehicle phone. When GNSS signal has the direction only from the antenna to the vehicle systems, GSM signals are transferred on both directions from the antenna to the vehicle telematics units and from vehicle telematics units to the antenna side.

eCall device including measurement and control units takes the positioning data from GPS Antenna, and its GSM antenna relation is active when the accident occurs. The internal boundary process of the eCall device is explained in Section-4 of this part.

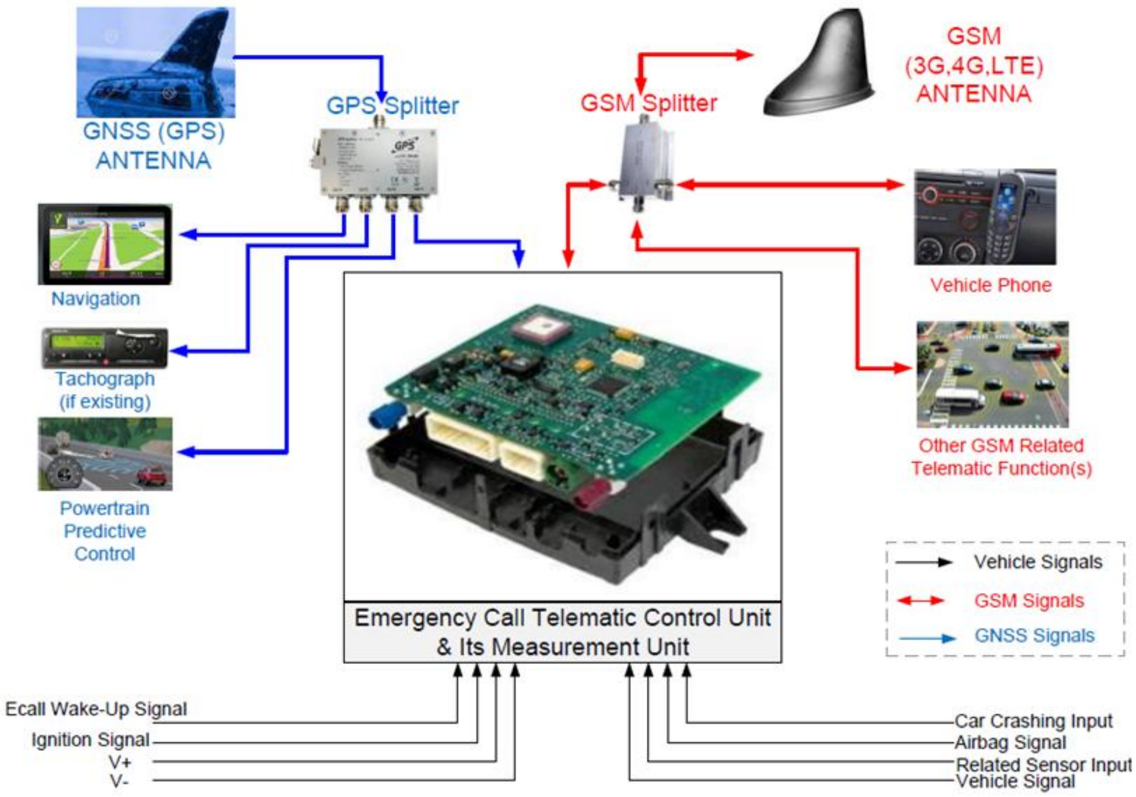

Figure 4.1 In-Vehicle eCall System Architectural Overview

The eCall device is related to the vehicle system in which the eCall device takes the vehicle information from when the emergency call is forwarded to the cellular tower. These units are [3];

- Sensor Systems
- Airbag Unit
- Telematic units
- Vehicle CAN-bus architectures

These units' relations are explained shortly to understand its working principle exactly. The sensor systems which has a connection with an eCall system in the vehicle includes the accelerometer to measure the direction and magnitude of the impacts. It has also a connection with sensor management system which collects the data from different type of sensors from the different sides of the vehicle such as vehicle speed, vehicle rotation etc. Next, the airbag unit enables the eCall system to understand which airbag in the vehicle is deployed such as front and driver side, front and passenger side, back and right side or back and left side. It includes the rollover system or the system like rollover functionality and it gives the airbag is opened signal to the related systems with its threshold values. Moreover, the telematics unit is the control unit of vehicle telematics systems and some of the information is received by eCall control unit from vehicle telematics units such as processed vehicle positioning information, vehicle speed information and time-related functions including transmission bandwidth. Another vehicle environment of eCall device is Vehicle CAN-Bus architecture. Vehicle serial data is transmitted in the telematic control unit and it is forwarded to the eCall Control unit via CAN-Bus communication. This information is defined in one of the grouped sequences in the architecture of CAN communication network. The CAN communication can be defined also another networking such as LIN, SAE standard etc.

In addition to the vehicle environment which is defined above paragraph, the crash severity needs to be defined and eCall device is needed to be informed about that. It is the function of probability outputs as vehicle speed, seatbelt status, impact type and curbside weight of the vehicle.

The eCall device including measurement unit and control unit is contended by the information below when the accident occurs [6]:

- Accident Information
- Vehicle Information
- Occupants
- Road Data
- Weather Conditions

The accident information can be implemented as frontal impact (front crash), side impact (crash from sides), rear end impact (rear-end collision) or rollover (overturned vehicle). Next, vehicle information can be analyzed in two groups. These are vehicle description and time functions. Vehicle description can be created by airbag information, hood and seatbelt when time functions can be impact speed, fire, and fuel leakage. Moreover, the occupant means the definitions of a number of occupants, occupant allocations and time of the accident. On the other hand, road information can be the vehicle direction, traffic flow, geographical area, and pavement. Finally, weather data explains the state of sky, precipitation, visibility and wind speed.

Taking the received information into consideration, the features below are emphasized:

- Vehicle Type
- Impact Type
- Accident Severity

➢ Location with the environmental status

According to impact and collision severity, eCall equipped vehicles are referred to the tests of NCAP. If the frontal impact occurs with a severe accident or minor accidents, it is tested with EU NCAP. Next, EU NCAP Side tests are for side accidents and EU NCAP whiplash tests are about the rear-end collisions.

4.1.2 eCall Component Hardware Details

Emergency Call device in vehicle eCall system consists of two main parts. These are emergency call control unit and emergency call measurement unit. Ecall control unit is the eCall device processor with its integrated parts as it is shown in Figure 4.2 at the left-hand side. On the other hand, eCall device measurement unit is the device user interface part which can include buttons, LEDs, lights, information screen as it is shown in Figure 4.2 at the right-hand side [161].

Control Unit Measurement Unit

Figure 4.2 eCall Component Hardware [161]

<u>-Different Application Types-</u>

In addition to them, the eCall system needs to have microphone system, speaker system and/or video systems. These systems can be integrated as it is described below:

➢ They can be integrated into the eCall device control unit.

➢ They can be adapted to the eCall device measurement unit.

➢ They can be set up in the vehicle system anywhere.

- They can be used on behalf of vehicle telematics units such as vehicle speaker systems, vehicle microphone system, vehicle telematics display

eCall device including measurement and control unit implements the vehicle data collection via CAN Bus architecture, there exists the audio input & output relation and it enables to make a localization and tracking processes [161].

-Operating Requirements-

The eCall device can have a display screen such as having 2 lines with 16 characters each. It can be also designed for different displays. Its temperature range is -25 to 70 C degrees for operation when the storage temperature ranges nearly between -40 and 85 C degrees. Its supply voltage can be 12 V or 24 V with respect to being passenger car application or heavy duty application. Generally, passenger car and light commercial vehicles starter batteries are 12 V when the starter battery of heavy-duty vehicles is 24 V. The standby current value can be estimated as 30 mA for 12 V eCall devices when its 24 V applications can be thought as 20 mA. Moreover, operating current of the power supply is about 3A for 12 V devices when 24 V devices are 1A as max. The device protection which means the cover of the device (device external surfaces -shell) can be produced as the materials fitting with IP-54 protection standard. Moreover, the electromagnetic compatibility (EMC) test requirements are defined with ECE-R10 standards. In these operating requirements, display and current values are the estimations when the other requirements are thought as mandatory [162].

-Connections-

The eCall device connector to enable the connections of the related vehicle system which is described in Figure 4.2 can be summarized with the Table 4.1 below.

As it is shown in Table 4.1, the device connections can be enabled by three or four connectors. These are Fakra connector for GSM Antenna, Fakra Connector for GPS Antenna [163] and Main Connector for Vehicle signal connections. The main connector can be applied to one main connector or two parts of the main connector. In Figure 4.2, it is shown that main connector has two parts. As it is investigated in USCAR connector requirements [164], if the numbers of pins are high in the connector system, it can be used with the sections as it is shown in Figure 4.2 including the main connector as two parts.

Table 4.1 eCall Device Connection Types

Connected eCall Device Part	Connected Device	Connector Type	Connector Property
eCall Control Unit	GSM Antenna	Fakra	Code-D
eCall Control Unit	GPS Antenna	Fakra	Code-C
eCall Control Unit	Airbag	Tyco-18 Pin (or Equal Design Specific Connector Types)	Airbag Signal
eCall Control Unit	Sensor Diagnostik Module	Tyco-18 Pin (or Equal Design Specific Connector Types)	Sensor Data
eCall Control Unit	Vehicle Plug-in Connector	Tyco-18 Pin (or Equal Design Specific Connector Types)	Supply and Ground Voltages
eCall Control Unit	Vehicle Plug-in Connector	Tyco-18 Pin (or Equal Design Specific Connector Types)	Ignition and Wake-Up Signals
eCall Control Unit	Vehicle Plug-in Connector	Tyco-18 Pin (or Equal Design Specific Connector Types)	Car Crashing Input
eCall Control Unit	Vehicle Plug-in Connector	Tyco-18 Pin (or Equal Design Specific Connector Types)	Other Vehicle Signals

The reason of using more than one section in the main connector can be;

- Protection of pinout-breakings
- Protection of Connector external surface
- Protection of pinout holes.

When the connector is getting out of its place or is setting into the place, the problems which are mentioned as protections above can occur if the connector is too long when it has lots of pinouts.

In addition to the information of main connector type, its internal pinouts need to be defined. In vehicle applications, there are three main usages of connector pin materials. These are tin, silver, and gold. The requirements allow the suppliers & Automotive OEMs to use these materials as connector pins. Its applications can be different. Tin material connectivity and signal quality are lower than silver and the same properties of the silver material are lower than gold material. Gold material is more expensive than silver material and the tin material is cheaper than silver material. Taking this information into consideration, it is logical to choose the gold material to have a good quality. But, the cost reduction topics due to high costs of the vehicles cause to change the gold material with the other materials if the design is completed with gold pinouts. On the other hand, sometimes there can be the communication problems in tin pinouts or its lifetime is shorter than the others. In this point of view, silver pinouts can be the best option to choose in the design concept. This pinout material information can be applied not only for Fakra Connectors but also for main connectors.

On the other hand, Fakra connectors are chosen by the application methodology via its functionality which is described in Appendix-A [163]. Appendix-A defines the color codes of the Fakra Connectors. The connector colors are defined via its applicational differences and these connectors have different poke-yoke in its structural shape. In this application of eCall device, GSM Fakra connector in eCall device can be chosen as Fakra Code-D which is Bordeaux color and it can be jack or plug. It depends on the design specification. By the way, it is a single connector. On the other hand, Fakra connector of eCall device for GPS Connection can be chosen as Fakra Code-C in Appendix-A which is Blue color, it can be jack or plug via its design concept and it is a single connector in this application.

4.1.3 eCall Component Electrical Interface in Vehicle System

4.1.3.1 Vehicle Electrical Connection via eCall Device

ECall device is needed to be integrated with the vehicle system connection in electrical interface. When the vehicle electrical connection schemes in Figure 4.3, it is obvious that the power connection and signal distributions are enabled by the protection units such as fuses, relays, power distribution boxes.

In Figure 4.3, red lines are the power lines (voltage signals) and black lines are the ground signals. Starter battery is connected to the vehicle system on behalf of its master switch which is associated with power distribution box. By the way, ignition switch and engine signals are also forwarded to the power distribution box in-vehicle system.

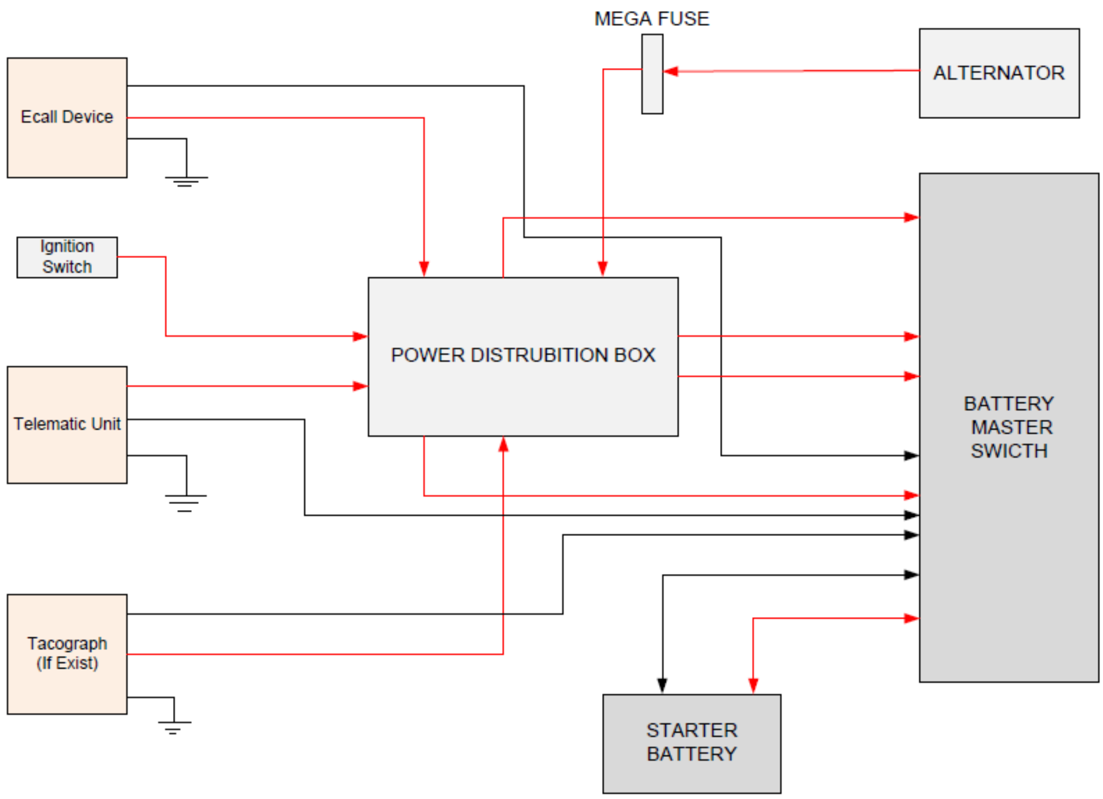

Figure 4.3 eCall Device Connection in Vehicle System

In Figure 4.3, the electrical components such as eCall device, tachograph or telematics units can have lots of input-output relations. Their signals can also go to the plug-in connections. In this figure, its power signals are tried to be analyzed and these units have 3 main important power signals. These are;

- Voltage Feed Signal
- Device Ground Signal
- Clear Ground Signal

Clear Ground is a ground term in the vehicle systems that are connected to the vehicle ground. That means there is more than one ground surface in the vehicles. These are;

- Vehicle Ground
- Component Ground
- System Ground
- Engine Ground

The component ground is the components own surface ground (V-). System ground and Vehicle ground is the same in passenger cars which means the whole vehicle ground is the same anywhere. Its heavy duty application is different. In heavy-duty vehicles, system ground can be different on vehicle front side which means the cab and engine ground and in-vehicle back side such as trailer etc. They can have a ground switch to make all of them the same or separate front and back side as different. Engine ground is generally connected to the vehicle ground in all types of applications. eCall device is an electrical component which is positioned in the cab of all types of vehicles and it has the vehicle ground. It can be called as also System Ground. The system (vehicle) ground (it is called as clear ground in the system) goes to the surface directly in Figure 4.3 for the components.

The ground of device-component such as eCall device is forwarded to the battery master switch and it is connected to the battery ground in this box. It is the components black lines in Figure 4.3 which goes to the battery master switch from the components.

The supplied feed of device-component such as eCall device is forwarded to the power distribution box. After the power signal goes through the power distribution box, it is connected to the battery master switch in this box. It is the components red lines in Figure 4.3 which goes to the battery master switch from power distribution box which comes from the components.

The component relation with Battery supply cannot be enabled without ignition and wake-up signals which are referred with the ignition switch in Figure 4.3.

As a conclusion of Part 4.1.1 and Part 4.1.3, the eCall device has a plug-in connector for power signals (ground signals and supply voltage), this plug-in connector can be connected to the other plug-in connectors and then these signals come to the power distribution box & battery master switch. Finally, this connection can be ready to use if the ignition, eCall wake signals are enabled by the vehicle control unit. In addition to them, this device is activated if the vehicle signals (car crashing, airbag inputs) come into the eCall device. Totally there are two steps:

- Step-1: eCall device is ready as Part 4.1.3.1
- Step-2: eCall is activated as Part 4.1.1

4.1.3.2 eCall Device PCM Electrical Interface

eCall device processors in control unit are designed for the vehicle applications with the properties below [164] :

- Safety

➢ Security
➢ Scalability
➢ Design to handle complex algorithms
➢ Performance
➢ Inbuilt interfaces such as CAN, LIN, SENT
➢ Emulation devices to interface with calibration tools during development

The silicon thickness and scalability can be described with different measurements. These are;

➢ High end
➢ Mid
➢ Low end
➢ Ultra low

Low and ultra low-end thickness for the silicon areas are used in the processor equipment which has the high accuracies.

The eCall device processor will be as it is shown in Figure 4.4.

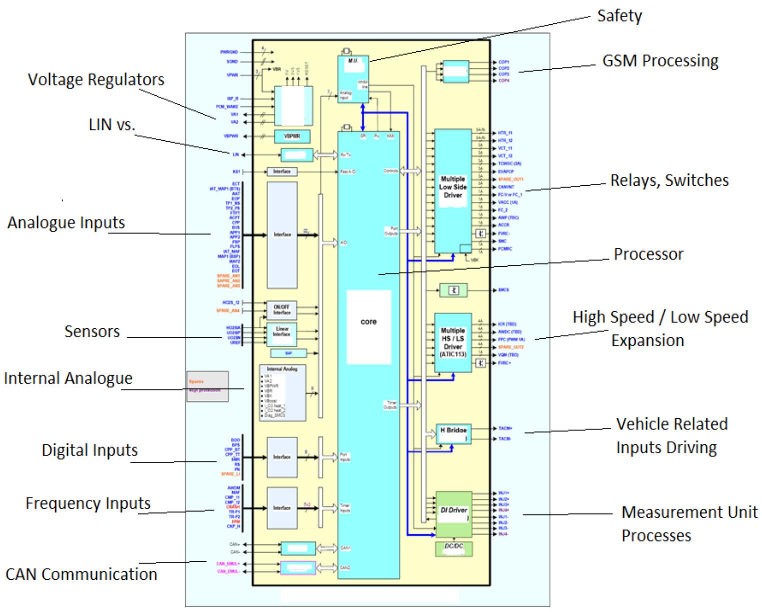

Figure 4.4 eCall Device PCM Interface

The main parts of PCM in Figure 4.4 is voltage regulators, LIN or equal communication type, analogue inputs, sensor inputs, internal analogue inputs, digital inputs, frequency inputs, CAN Communication, safety side, GSM Processing, relay and switches, main processor, high and low speed expansion, vehicle related driving inputs and measurement unit process.

Voltage Regulators in PCM (Power Control Module) of eCall device in Figure 4.4 is the boost processor which enables the different voltage types to the device.

LIN or equal communication in PCM of eCall device in Figure 4.4 is the alternative communication types which are slower than the CAN Communication. It can enable to have a calibration process and diagnostic process for the device equipment. It enables to reach the processor parameters like CAN communication.

Analogue inputs in PCM of eCall device in Figure 4.4 are the analog information of the processor such as SOS button inputs.

Sensor inputs in PCM of eCall device in Figure 4.4 are the sensor information of the processor such as an accelerometer which enables the vehicle speed. It comes from sensor diagnostic module of the vehicle system.

Internal analog inputs in PCM of eCall device in Figure 4.4 are the processor internal process which is enabled by the function of analog inputs with the safety requirements.

Digital inputs in PCM of eCall device in Figure 4.4 are the digital data of the processor such as automatic eCall device activation signal which works ‘if and only if’ the accident occurs.

Frequency inputs in PCM of eCall device in Figure 4.4 are the data which needs to create the transfer function via signal properties of amplitude and time. Parameters of sending data set to the cellular tower can be given as an example of this part.

CAN Communication is the communication in PCM of eCall device in Figure 4.4 with the other telematic units with high speed and low speed. Vehicle telematics control unit can send the vehicle data such as positioning information, vehicle identity number.

Safety side module in PCM of eCall device in Figure 4.4 is the data of functional safety which is fitting with the functional standards such as SAE standards and the processor information are defined in these safety requirements with this module.

GSM Processing inputs in PCM of eCall device in Figure 4.4 is the communication of eCall device of vehicle system with the cellular tower network when the accident occurs.

Relay, switches inputs in PCM of eCall device in Figure 4.4 is the inputs of power signals which go to the relay and switch connections in the vehicle systems.

High speed and low-speed expansion in PCM of eCall device in Figure 4.4 enable the communication speed being expanded as high speed or being expanded as low speed. As an example, it can be used in the CAN dB files if their messages exceed the message limits.

Vehicle-related inputs in PCM of eCall device in Figure 4.4 enables to take the signals from the related vehicle systems if it is not defined in any other side of the PCM inputs.

Measurement unit processor in PCM of eCall device in Figure 4.4 enables to have the process of measurement inputs such as audio and speaker system inputs.

These properties and units are defined in the real circuit as it is shown in Figure 4.5 below:

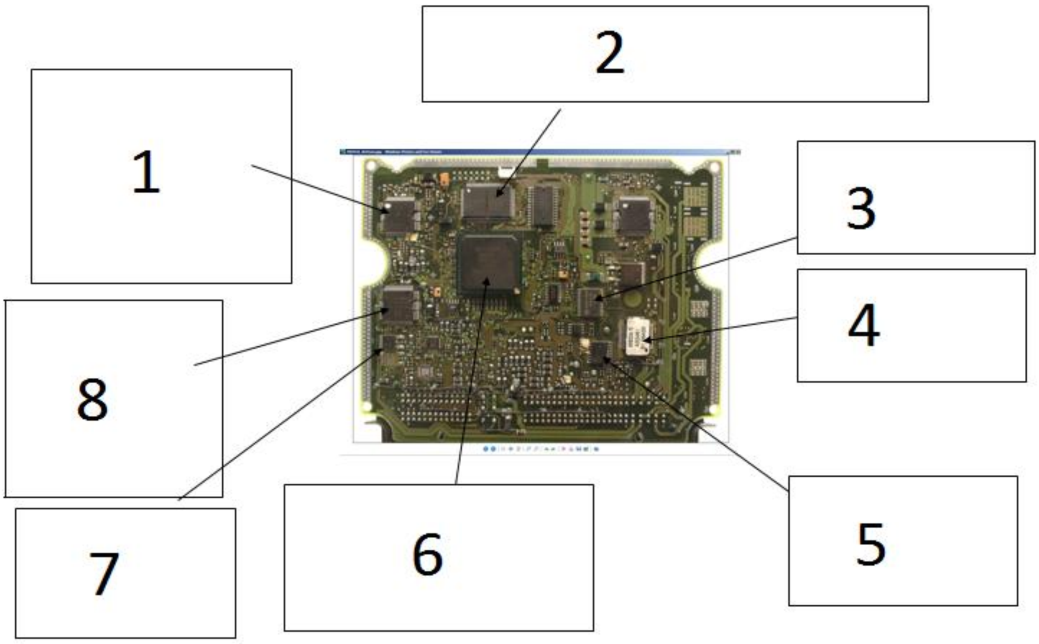

Figure 4.5 Inside Architecture of eCall Device PCM

Side-1 in Figure 4.5 is the voltage regulator – provides internal voltage supplies to the processor and peripheral chips & external reference voltages to the sensors. Most PCM suppliers will integrate additional functionality within this chip i.e. CAN/LIN/ISO drivers, uP (unit Processor) watchdogs.

Side-2 in Figure 4.5 is Memory expansion – Not all uP permit external memory expansion since the bus is not taken outside of uP package. Having an external bus makes the module more vulnerable to EMC and external memory is expensive. It takes up PCB real estate. Best design practice is designed uP with sufficient memory.

Side-3 in Figure 4.5 is the ignition inputs comes from ignition and wake-up signals and it sends a low power signal to driver stage in the ignition coil. It is applied if the device is in 4 – 6 channel devices.

Side-4 in Figure 4.5 is the driver can be used in various types such as low speed, high speed or so on.

Side-5 in Figure 4.5 is the sensor detection ASIC can be used for sensor information which is described in Figure 4.4.

Side-6 in Figure 4.5 is the microprocessor and its main important point is about silicon thickness what can be changed between 60 and 150 nm. Its packages standard can have changes in voltage regulators. Its relation also with PCB packaging is another important point.

Side-7 in Figure 4.5 is the high current discrete drivers for vehicle data such as activation signals.

Side-8 in Figure 4.5 is the multiple low side drivers which enable the ground path for relays, switches, solenoids. It is located on cooling bank.

4.1.4 Internal Boundary Diagram of eCall Device

The architecture diagram of emergency call measurement & control unit in the ecall-equipped vehicle is shown in Figure 4.6. This Figure and its explanation define the working structure of emergency call device with respect to internal and external boundaries inside of the vehicle. When internal boundaries describe the internal process of ECall equipment, external boundaries explains the process of other vehicle equipment on the emergency situation and vice versa.

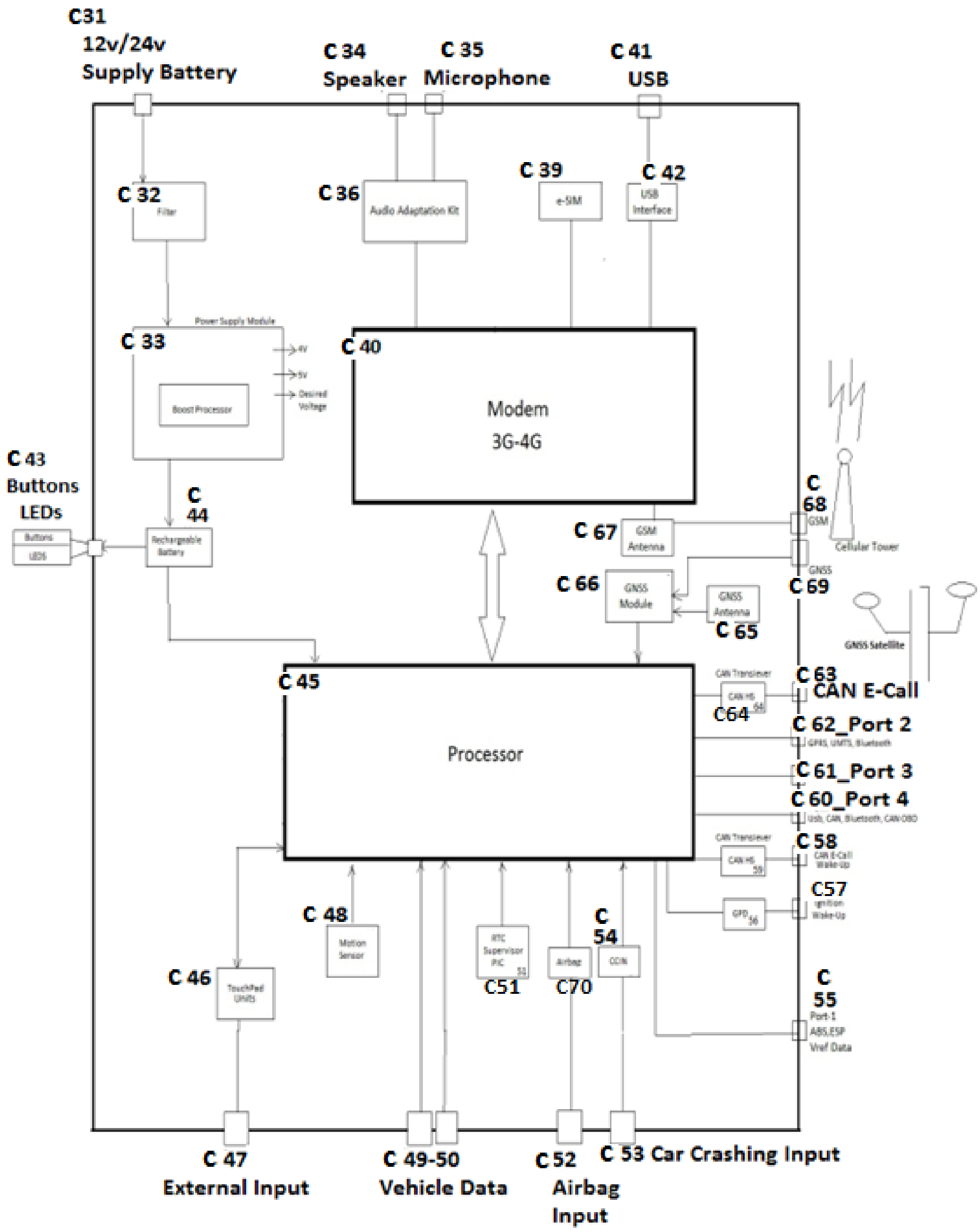

Figure 4.6 Internal Diagram of ECall Measurement & Control Unit

24 or 12 volt supply voltage (c31) of emergency call unit exists in the device. Boost processor (33) is in progress after filtration process of its unit (c32) with the supply voltage and provides the different types of voltages such as 3V, 4V, 5V for different applications. Next, there exists backup battery (c44) which is generally used in eCall system products. The power is forwarded to this battery and it protects the device connections from small power losses of the starter battery. The backup battery is also connected to a processor which is control system design equipment. Moreover, GNSS inertial module (c66) provides the location data into the eCall-Unit which is processed

in microprocessor(c45). Some parameters of minimum data set such as location, accident severity are processed to send the data to the cellular tower when it takes the vehicle data inputs (c49,c50). Measurement Unit which is the user-interface side of emergency call device is presented with touchpad unit (c46) in the architecture which defines the related command with its external input (c47). It is the external force-output if the emergency equipment is Manuel eCall device. If ECall device is only automatic ECall equipment, this side is removed from architecture. System control is made by this input for manual devices. When it is activated, PIC supervisor (c51) enables programming with its codes via own-logical approach. The system is ready to work when the ignition and wake-up signals (c57) are turned on. The supply voltage is also turning on with these signals. On the other hand, ignition can be activated but the engine is not started in some cases. In these manners, the situations are decided by ignition signals. If both ignition and eCall wake-up signals are active, emergency call system can be used. When the emergency case occurs, emergency response system is activated by the signals such as motion sensor input (c48), airbag input (c70) and crashing input (c53). CAN-eCall (c63) signal determines the CAN Communication after the wake-up signals are turned on. It’s CAN Communication is the high-speed CAN which carries the accident-related data such as accident location, the severity of the accident, vehicle identification number. GNSS module (c66) provides the location information. Its first data are provided by outer GNSS antenna input (c69). There exist the communication ports. Port-1(c55) in the architecture is vehicle reference data including abs (active breaking system), esp (electronic stability programmer) data. Port-2(c62) is gprs, umts and Bluetooth data when port-3(c61) defines the machine to machine signal. Next, Port-4 describes the on-board diagnostic signal and Bluetooth signal. These ports can be modified via vehicle communication network requirements. Modem (c40) side of ecall control unit processor exists to enable cellular communication including audio tool (c36) and USB signals. The Audio tool includes a loudspeaker (c34) and microphone (c35) at the external side in the body of ecall control unit. Led (light) and measurement unit buttons (c43) are in usage with the signal come from backup battery when the accident occurs.

4.1.5 P-Diagram of eCall Component Device in the Vehicle

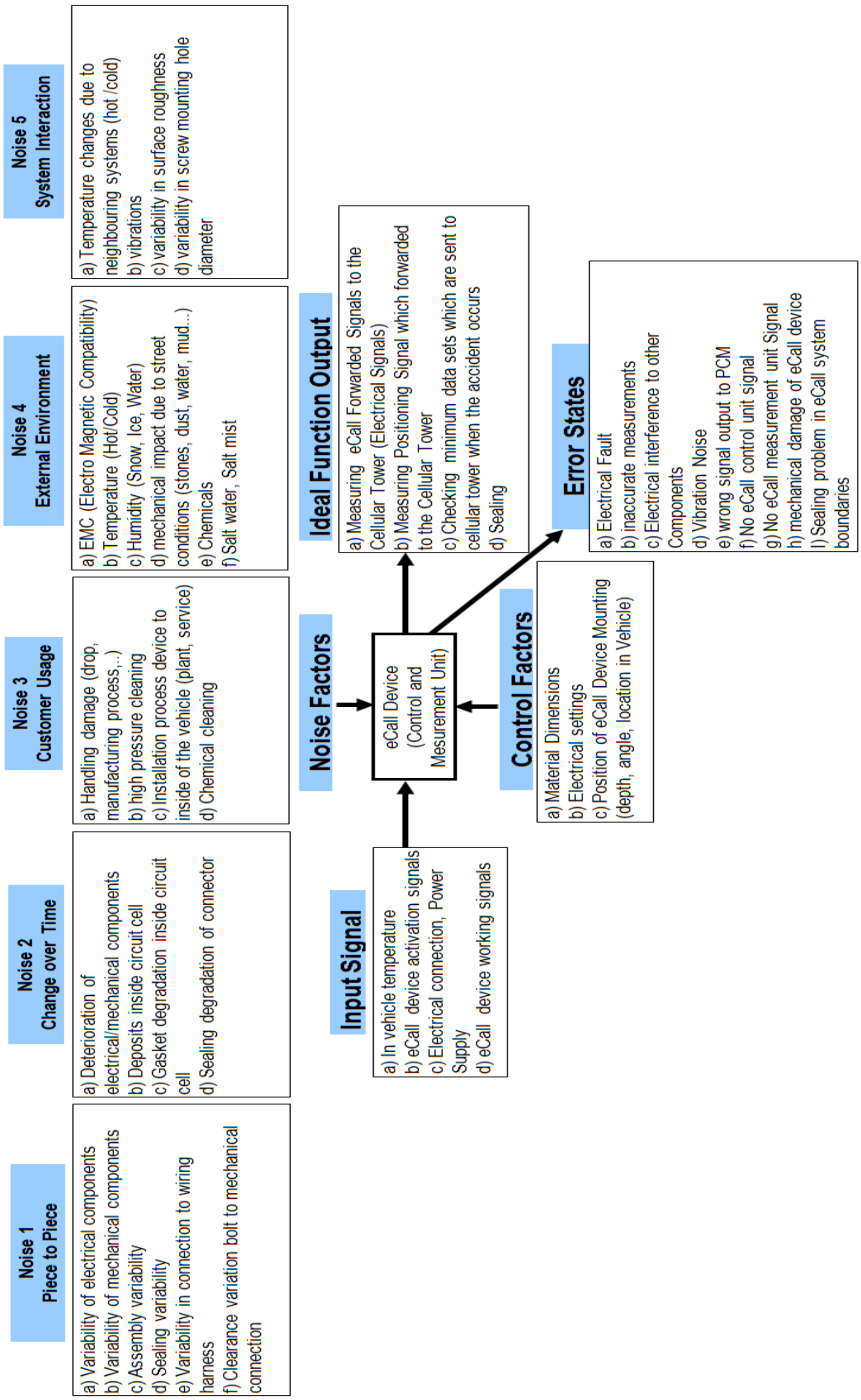

Figure 4.7 P-Diagram of eCall Device

eCall device Boundary diagram has been defined in Part 4.1.4. In this part, the P-Diagram of this Boundary is described. P-Diagram of the eCall device includes the parts below, which is also defined in Figure 4.7:

- Device Inputs
- Device
- Device Noises
- Device Control Factors
- Device Error States
- Device Ideal Output Function

eCall Device Input Signals are the device temperature, eCall device activation signals, electrical connections, power supply and eCall device working signals. eCall device activation signals and working signals are defined in Part 4.1 with Figure 4.3 and Figure 4.6. Vehicle power supply and electrical connections are defined until this section in Part 4.1.3.

eCall Device Noises can be described in 5 sections as in Figure 4.7. These are;

- Piece to Piece Noises
- Change over time noises
- Customer Usage Noises
- External Environment Noises
- System Interaction Noises

‘Piece to Piece’ noises are the noise of the device equipment which are affected by each other. These noises can be; electrical and mechanical component variability, assemble variability, sealing variability, wiring harness connection variability, clearance of mechanical connection bolts. The component and functionality relations due to these reasons can cause the error states as ‘piece to piece noises’.

The noises which are the time functions are ‘change over time noises’. These can be components deteriorations, deposits inside circuit cells, gasket degradation inside circuit cells and connector sealing degradation. Life cycles of the components and connections are the important factors in this type of noises.

The Customer usage noises can be the cleaning, installation and handling damage due to manufacturing, drop. The wrong Installation of the eCall device can be made in plant or services. On the other hand, cleaning due to high-pressure devices or chemical materials can cause problematic status in electrical connection and measurement unit of the eCall device.

The external environment noises are due to the environment and its main important point is the electromagnetic compatibility which the device is regulated by ECE-R10. The other noises due to the environment can be mechanical noises such as temperature, humidity and mechanical impact due to stress conditions. Temperature range is nearly defined in the Part 4.1.2. Humidity rate needs to be in the range of the technical specification of the eCall device when a mechanical impact due to the stress can be occurred in the installation or due to the wrong positioning of the device. The other environmental noises can be chemical and saltwater conditions. If the salt mist or chemical flows are contacted with device electrical connections due to the different environmental conditions, it causes to have an error state in the device.

Finally, the noise of system interaction is emphasized. Vibration, temperature status due to neighboring systems of eCall device and variability's of surface roughness and screw mounting can be the system interaction problems. Vibration can occur if the device is not set exactly or device is vibrated when variabilities' are about mechanical operations. If the components or devices which are set next to the eCall device have upper-temperature value or lower temperature value than the operating requirements of the device, this type of problem can be occurred due to the other devices.

These noises can cause to have error states and these error states try to be controlled by control factors; then the ideal output functions in Figure 4.7 try to be enabled. The ideal output functions are data sets which are sent to the cellular towers, positioning data of GNSS, output data of GSM communication system and sealing validation. If these results are enabled correctly and their functionalities are Ok to use, the system can be defined as ideal.

The control factors of error states can be electrical settings, the location of device & material and its dimensions. According to error state types of the eCall device, these control factors, noises and also error states can be defined and the control factors can be improved.

Error states analyze will continue with the next part in Robustness Check List (RCL) which makes a correlation between error states, noises and verification tests. The error states in the eCall device can be electrical faults (Error States-A), incorrect measurements (Error States-B), electrical interface to other components (Error States-C), vibration noises (Error States-D), no eCall signals in control unit or measurement unit (Error States-F&G), wrong signal forward to PCM (Error States-E), mechanical damage of eCall device (Error States-H) and Sealing problems in eCall Boundaries (Error States-I).

4.1.6 RCL of eCall Component Device in the Vehicle

RCL is the Robustness Check List which is the integration of error states, noises and their solution tests as verification methods. Noises and error states are defined in the last section in P-Diagram. Verification Tests which are sequenced below are the tests which are fitting to the ISO, CEN, EN, ETSI standards and their standard flows are explained in Part 4.1.4.

The Verification tests to fix the error states due to the noises are investigated in four sections. These are;

- Mechanical Tests
- Electrical Tests
- Functional Tests
- Environmental Test
- Software or Diagnostic Tests

These tests are applied to the issue in two structures. These are;

- Component-Device Level Tests
- Vehicle Level Tests

In this Part, eCall device level tests and their relationship with the error states will be described. Its vehicle level tests can be defined when the component is tested in the vehicle at system level.

Before defining verification tests, the relation between error states and noises are defined in Figure 4.8. Errors states are matched with the numbers between ‘A and G’ and noises are grouped as ‘Noise-1 to Noise-5’ as it is emphasized in P-Diagram. The noise types are named as ‘a,b,c,d,e and f’ in these Noises 1-5. The noise and error state relation is described with three meanings. These are;

- ‘ ● ‘ : Strong Relation
- ‘ ○ ’ : Weak Relation
- ‘Empty’: No Relation

The error states and noises can be increased when the eCall devices are actively used because of its error states can be followed in the customer usages after the common usages with the eCall equipped vehicle regulation in 2018.

	ERROR STATES
I	Sealing Problem in eCall System Boundaries
H	mechanical damage of eCall device
G	No eCall signal in measurement unit
F	No eCall signal in control unit
E	wrong signal output to PCM
D	Vibration Noise
C	Electrical interference to other Components
B	inaccurate measurements
A	Electrical Failure

		Metric	Range	A	B	C	D	E	F	G	H	I
	NOISE 1: Piece to Piece Variation											
a)	Variability of electrical components			●	●	●		●	●	●		
b)	Variability of mechanical components			●	●		○					
c)	Assembly variability						○		○	○		
d)	Sealing Variability										○	●
e)	Variability in connection to wiring harness			○	○				○	○		
f)	Tolerance Variability in Mechanical Connections						●				●	
	NOISE 2: Change Over Time											
a)	Deterioration of electrical/mechanical components			●	●	○	○		○	○		
b)	Deposits inside eCall circuit cells			○	○							
c)	Gasket degradation inside eCall circuit cells			○	○							
d)	Sealing degradation of connector								○	○		●
	NOISE 3: Customer Usage											
a)	Handling damage (drop, manufacturing process,..)			●	●	○	●	●	●	●	●	
b)	high pressure cleaning							○				
c)	Installation process eCall device in Vehicle (plant, service)			●	●	○	○		●	●		
d)	Chemical Cleaning Problems			○					○	○	●	○
	NOISE 4: External Environment											
a)	EMC (Electro Magnetic Compatibility)			●	●			●				
b)	Temperature (Hot/Cold)			○	○		○	○	○	○		
c)	Humidity (Snow, Ice, Water)			○	○			○	●	●		
d)	mechanical impact due to street conditions (stones, dust, water, mud...)			○	○		●	○			●	
e)	Chemical Effect			○					○	○	●	○
f)	Salt water, Salt mist			○	○							
	NOISE 5: System Interaction											
a)	Temperature changes due to neighbouring systems (hot /cold)											○
b)	vibrations			○	○		●	○				
c)	Surface Structure Changes					○					●	●
d)	variability in screw mounting hole diameter										○	

Figure 4.8 Error State & Noises of eCall Device

In Figure 4.8, Error states-A is related with Noise-1 item-a and item-b; Noise-2 item-a; Noise-3 item-a & item-c and Noise-4 item-a as strong relation. Its weak relation is with Noise-1 item-e; Noise-2 item-b & item-c; Noise-3 item-d; whole Noises-4 without item-a and Noise-5 item-b.

In Figure 4.8, Error states-B is related with Noise-1 item-a and item-b; Noise-2 item-a; Noise-3 item-a and item-c and Noise-4 item-a as a strong relation. Its weak relation is with Noise-1 item-e; Noise-2 item-b and item-c; all Noises-4 without item-a & item-e and Noise-5 item-b.

In Figure 4.8, Error states-C has strong relation with Noise-1 item-a. Its weak relation is with Noise-2 item-a, Noise-3 item-a and item-c and Noise-5 item-c.

In Figure 4.8, Error states-D has strong relation with Noise-1 item-f; Noise-3 item-a; Noise-4 item-d and Noise-5 item-b. Its weak relation with Noise-1 item-b & item-c; Noise-2 item-a; Noise-3 item-c and Noise-4 item-b.

In Figure 4.8, Error states-E has strong relation with items-a of Noise-1, Noise-3 and Noise-4. Its weak relation is with Noise-3 item-b; Noise-4 item-b,c,d and Noise-5 item-b.

In Figure 4.8, Error states-F& G has strong relation with items-a of Noise-1 and Noise-3 and items-c of Noise-3 and Noise-4. Its weak relation is with Noise-1 item-c and item-e; Noise-2 item-a & item-d, Noise-3 item-d; Noise-4 item-b & item-e.

In Figure 4.8, Error states-H has strong relation with Noise-1 item-f; Noise-3 item-a & item-d, Noise-4 item-d & item-e and Noise-5 item-c. Its weak relation is with items-d of Noise-1 and Noise-5.

In Figure 4.8, sealing failure states (error state-I) is related with items-d of Noise-1 and Noise-2; and Noise-5 item-c as a strong relation. Its weak relation is about Noise-3 item-d, Noise-4 item-e and Noise-5 item-a.

After the error states are defined with error states; these errors are associated with the verification methods as it is shown in Figure 4.9.

The noise and verification method relation in Figure 4.9 is described with two meanings. These are;

- ‘X‘ : Relation Exist
- ‘Empty’ : No Relation

In addition to them, the test type and test names in Table 4.2 are charted with the relations including two meanings. These are;

- Gray Area inside ‘Exist‘: Relation Exist
- ‘Empty’ : No Relation

VERIFICATION METHODS VS NOISES		1 Media Leakage Test	2 Low Temperature Operation	3 High Temperature Exposure Test	4 High Temperature Operation	5 Powered Thermal Cycle Operation	6 Thermal Shock Resistance Test	7 Thermal Shock Endurance Test	8 Humidity Temperature Cycle	9 Immersion Test	10 Car wash/Heavy splash/shower	11 Dust Test	12 Vibration Endurance Test	13 Package Drop Test	14 Handling Drop Test	15 Connector & lead lock strength Test	16 Salt mist atmosphere	17 Torque Lead Lock Strength Tests	18 High Temperature/High Humidity Endur	19 EMC Test	20 Electrical Functionality Test	21 Signal Stability Test	22 Response Time Tests	23 Electrical Failure Strength Tests	24 Short Circuit & Open Circuit Test	25 No load acceleration/deceleration	26 High speed acceleration/deceleration
	NOISE 1: Piece to Piece Variation																										
a)	Variability of electrical components				X				X							X				X	X	X	X	X	X		
b)	Variability of mechanical components												X														X
c)	Assembly variability	X												X	X											X	X
d)	Sealing Variability	X								X																	
e)	Variability in connection to wiring harness															X						X			X		
f)	Tolerance Variability in Mechanical Connections												X			X											X
	NOISE 2: Change Over Time																										
a)	Deterioration of electrical/mechanical components			X	X	X	X	X											X							X	X
b)	Deposits inside eCall circuit cells																									X	X
c)	Gasket degradation inside eCall circuit cells	X	X	X	X	X	X																			X	X
d)	Sealing degradation of connector	X	X	X	X	X	X																			X	X
	NOISE 3: Customer Usage																										
a)	Handling damage (drop, manufacturing process,..)													X	X												
b)	high pressure cleaning										X																
c)	Installation process eCall device in Vehicle (plant, service)													X	X												X
d)	Chemical Cleaning Problems	X								X							X							X	X		
	NOISE 4: External Environment																										
a)	EMC (Electro Magnetic Compatibility)																			X							
b)	Temperature (Hot/Cold)	X	X	X	X	X	X		X	X									X								
c)	Humidity (Snow, Ice, Water)								X	X									X								
d)	mechanical impact due to street conditions (stones, dust, water, mud...)									X	X			X	X												
e)	Chemical Effect	X								X							X							X	X		
f)	Salt water, Salt mist											X					X										
	NOISE 5: System Interaction																										
a)	Temperature changes due to neighbouring systems (hot /cold)	X	X	X	X	X	X			X																	
b)	vibrations												X			X						X					
c)	Surface Structure Changes	X								X			X	X	X		X	X		X				X			
d)	variability in screw mounting hole diameter																	X									X

Figure 4.9 Noises and Verification Methods of eCall Device

The verification methods are the tests to fix the related problems if it can be corrected. The test types are mentioned at the beginning of this Part. First of all, the tests in Figure 4.9 is explained in Table 4.2 via being mechanical, electrical, environmental and diagnostic (software) tests. Chart-Relation (Empty/Gray Area) between them are defined at last page.

Table 4.2 Test Types of eCall Device

Test Name	Test Types				
	Mechanical	Electrical	Functional	Enviromental	Software
Leakage Test				Exist	
Low Temperature Operation	Exist		Exist		
High Temperature Exposure	Exist				
High Temperature Operation	Exist		Exist		
Powered Thermal Cycle	Exist				
Thermal Shock Resistance	Exist				
Thermal Shock Endurance	Exist				
Humidity Temperature	Exist				
Immersion Test				Exist	
Vehicle Wash				Exist	
Dust Test				Exist	
Vibration Endurance					
Package Drop	Exist				
Handling Drop	Exist				
Connector Lead Lock		Exist			
Salt Mist Atmosphere				Exist	
Torque Lead Lock	Exist				
High Temperature Humidity					
EMC		Exist	Exist		
Electrical Functionality		Exist			
Signal Stability		Exist	Exist		
Response Time		Exist	Exist		Exist
Electrical Failure Strength		Exist			Exist
Open-Short Circuit Tests		Exist			Exist
No Load Acceleration/Deceleration				Exist	
High-Speed Acceleration / Decelaration				Exist	
Fluid Compatibility				Exist	
Inrush current tests		Exist			

After understanding which tests mean the mechanical status or electrical status or environmental status in Table 4.2 above, Figure 4.9 can be discussed.

Noise-1 Tests in Figure 4.9;

In Figure 4.9, Noise-1 Item-a is related to Tests 4-8-15 and the tests between 19 and 24. Item-b is related to the test12 and Test 26 when item-c is about Tests 1-13-14-25-26. Next, Noise-1 item-d is related to Tests 1-9 while Noise-1 item-e is related with the Tests-15-21-24.Moreover, Noise-1 item-f is related with Tests 12-15-26.

Noise-2 Tests in Figure 4.9;

In Figure 4.9, Noise-2 Item-a is related to Tests between 3 and 7 and Tests 18,25,26. Next, item-b is about te Tests 25 and 26 when item-c and item-d are associated with the Tests between 1 and 6 and Tests 25,26.

Noise-3 Tests in Figure 4.9;

In Figure 4.9, Noise-3 Item-a and item-c are related to Tests 13 and 14 when the item-b is about Test-10. Additionally, item-c has Test-26. Next, item-d is associated with Tests 1-9-16-23-24.

Noise-4 Tests in Figure 4.9;

In Figure 4.9, Noise-4 Item-a is about Test-19 when Tests 1 to 6 & Tests 8,9,18 can be applicable if the item-b exists. When the item-c is an error state, tests 8,9,18 can be applied. Item-d can be compensated with the tests 9,10,13,14 with its correct analyze. Finally, item-e is about Tests 1-9-16-23-24 while item-f is about the tests 11 and 16.

Noise-5 Tests in Figure 4.9;

In Figure 4.9, tests between 1 and 6 and 9 are applicable if the problem is item-a. When item-b cause to have a problem about the tests 12,15 and 21; item-c may be compensated with Tests 1-9-12-13-14-16-17-19-23. Moreover, item-d can be checked with Tests 17 and 26.

4.1.7 Vehicle Application: Mounting Location Strategy of Emergency Call Control Unit in Passenger Cars

The eCall device in the vehicle system can include two main parts as it is emphasized in Part 4.1.2 These are eCall control unit and eCall measurement unit. The aim of this part is to analyze the mounting location of eCall control unit with respect to technical requirements and cost status. To define the possible mounting locations; the main connected equipment to the eCall device such as telematic control unit (or Power Control Module), communication antenna which affects the communication signal quality needs to be described with its positioning in the vehicle. Due to this reason, mounting location alternatives of the telematic control unit are reviewed at the first section in Part 4.1.7.1. Then; the mounting location alternatives of eCall control unit are described via being near to the telematic control unit or communication antenna in Part 4.1.7.2. The mounting location correlations of eCall control unit and telematic control unit are explained by the communication signal quality and its electrical properties & cost status in Part 4.1.7.4 which enables to see the optimal alternatives of eCall control unit mountings. Before defining Part 4.1.7.4, possible electrical connections between eCall device and TCU; and between eCall device and communication antennas are expressed with the lengths of wirings in Part 4.1.7.3. It enables to see the connection details and calculating the cost comparisons of different mounting locations.

4.1.7.1 Mounting Location Possibilities of Telematic Control Unit

Telematic Control Unit (TCU) is an electronic module in the vehicle system which manages the telematic functions in the vehicle such as navigation, display, eCall service, filo service information, settings. It can be used in the vehicle with the application variants as below:

- Power Control Module (Main Control Unit) of the vehicle can be different and telematic control unit can be different;
- Power Control Module (Main Control Unit) can be integrated with telematic control unit;
- There can be more than one control unit as Power Control Module (PCM) when the telematic control unit is different, and telematic control unit can be connected to the related PCMs.

In this point of view, telematic control unit or Integrated Unit of Power Control module & telematic control unit is analyzed via mounting location because of the fact that eCall device control unit is associated with the telematic control unit which has the main connections with each others. Figure 4.10 below is an example passenger car lateral and top views which shows the possible Telematic Control Unit mounting locations.

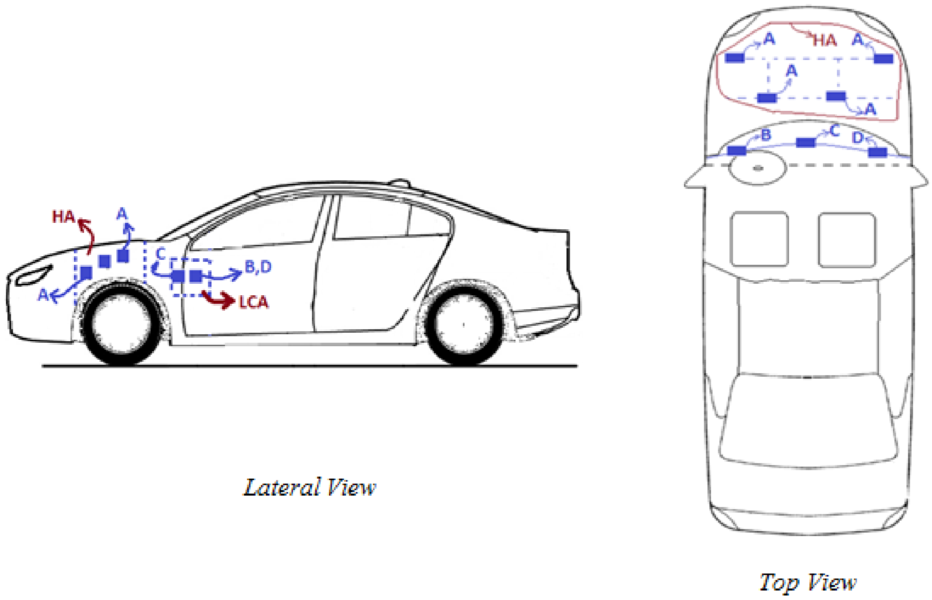

Figure 4.10 Vehicle View of Possible TCU Mounting Locations

These are Vehicle hood area called ‘HA’ and Lower cockpit area called ‘LCA’ in Figure 4.10. Hood area is the front side of the vehicle which includes the vehicle equipment such as starter battery, engine etc. On the other hand, the other common possible area can be lower cockpit area (LCA). Lower cockpit area can be expressed with the backside of the lower cockpit or front side. The Front side of the lower cockpit is the place which can be seen by the passenger and driver and it includes the surface in the cab-inside. Instrument cluster, steering wheel, and telematic displays are integrated to the front side of the lower cockpit.

Backside of Lower cockpit (LCA) includes the connections of the units of a front side. It can include also the control units and their connection areas. HCA and LCA areas are defined with the example picture in Figure 4.11 to understand the places exactly [198].

Secondly, the possible mounting location places such as A, B, C, D in the mounting areas of HA and LCA are explained. Place-A can be at the location in the hood inside area anywhere. Its exact point is not important for the study because the positioning is reviewed via an electrical connection such as wiring length, connectors, and the cost status. In addition, Place-B and Place-D are thought as symmetrical locations in LCA.

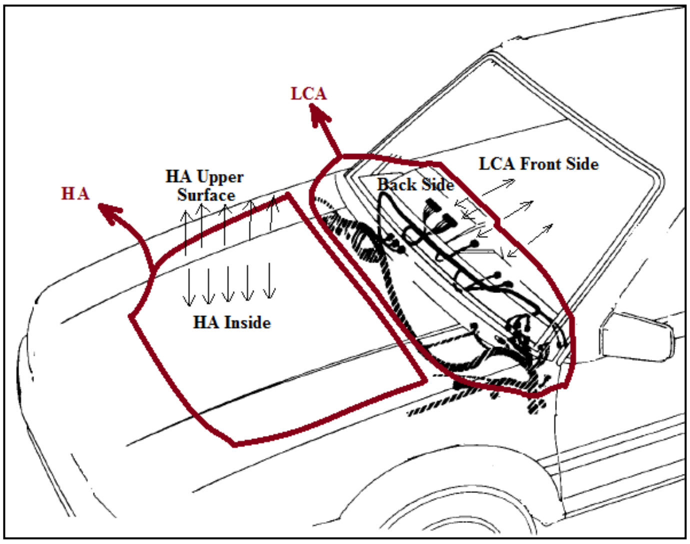

Figure 4.11 Vehicle View of Hood and Lower Cockpit Area [198]

They are at the right and left sides in LCA horizontally and their mounting height is nearly the same with each other as it is shown in Figure 4.11. Finally, Place-C may be on the middle side of LCA when it is looked at the top view and its height can be nearly the same with Place-B or Place-D.

Taking telematic unit possible mounting locations into consideration, the location places (A,B,C,D) and areas (HA, LCA) definitions are emphasized to understand where one of main eCall control unit connection is forwarded. After explanations of TCU locations, eCall control unit locations will be summarized in the next section in Part 4.1.7.2.

4.1.7.2 Mounting Location Possibilities of eCall Control Unit

Emergency Call Control Unit (eCall-ECU; eCall control unit) is an electronic module in the vehicle system which manages the emergency call system functions in the vehicle such as sending accident data to the emergency services, collecting minimum data sets which are sent to the emergency stations, eCall processes, its settings. eCall control unit can have different types. These are Manual eCall Device or Automatic eCall device. Manual eCall device is triggered manually when the accident occurs [143]. Automatic eCall device is activated automatically when there is an accident. When manual eCall device has the buttons as it is shown in Figure 4.2, automatic eCall device does not have any buttons and the device is connected to the emergency services directly when the accident occurs.

In addition to the eCall device types, eCall-ECU can be used in the vehicle with the application variants as below:

- App-1: eCall Measurement Unit with the buttons does not exist (Displays are enabled by vehicle units) and eCall control unit can be a unique device in the vehicle system; (as the Automatic eCall device).
- App-2: eCall Measurement Unit can be different module and eCall control unit can be different device in the vehicle system; (as the Manual eCall device)
- App-3: eCall Measurement Unit can be integrated with eCall control unit and the integrated kit (control & measurement units) can be one integrated kit in the vehicle system. (as the Manual eCall device)

In this point of view, eCall control unit or eCall integrated kit including control & measurement units are analyzed via mounting locations. If the automatic eCall device is used (App-1), its control unit can be adapted anywhere. In addition, if manual eCall device is used and its measurement unit is different from the control unit (App-2), its control unit can be adapted anywhere while the control unit adaptation needs to be reachable by driver and passengers if the Manual eCall device is used as an integrated kit (App-3).

By the way, eCall devices will be an obligation in the passenger cars on 31 March 2018 in Europe [2]. After the first usage periods, Manual eCall devices are restricted and all eCall devices will be turned to the automatic eCall device [195]. In this point of view, App-1 and App-2 are the common usage variants when App-3 is a usage type which is referred to the restricted time period.

Figure 4.12 below is an example passenger car lateral and top views which shows the possible eCall Control Unit mounting locations.

First of all, the possible mounting location areas are described. These are Vehicle hood battery area called as ‘HBA’ and Lower cockpit area called ‘LCA’ in the figure above. Hood Battery area is at the front side of the vehicle where the starter battery is set up. Moreover, the other common possible area can be lower cockpit area (LCA) which is also explained in Part 4.7.1.1.

Secondly, the possible mounting location places such as M, N, R, P, L, K in the mounting areas of HBA, LCA and the roof-inside in Figure 4.12 are explained. Place-M can be at the location in the hood inside battery area due to the fact that eCall control units can be adapted to the vehicle in the hood inside area such as near to the starter battery [197]. In addition, Place-N and Place-R are thought as symmetrical locations in

LCA. They are at the right and left sides in LCA horizontally and their mounting height is nearly the same with each other as it is shown in Figure 4.12.

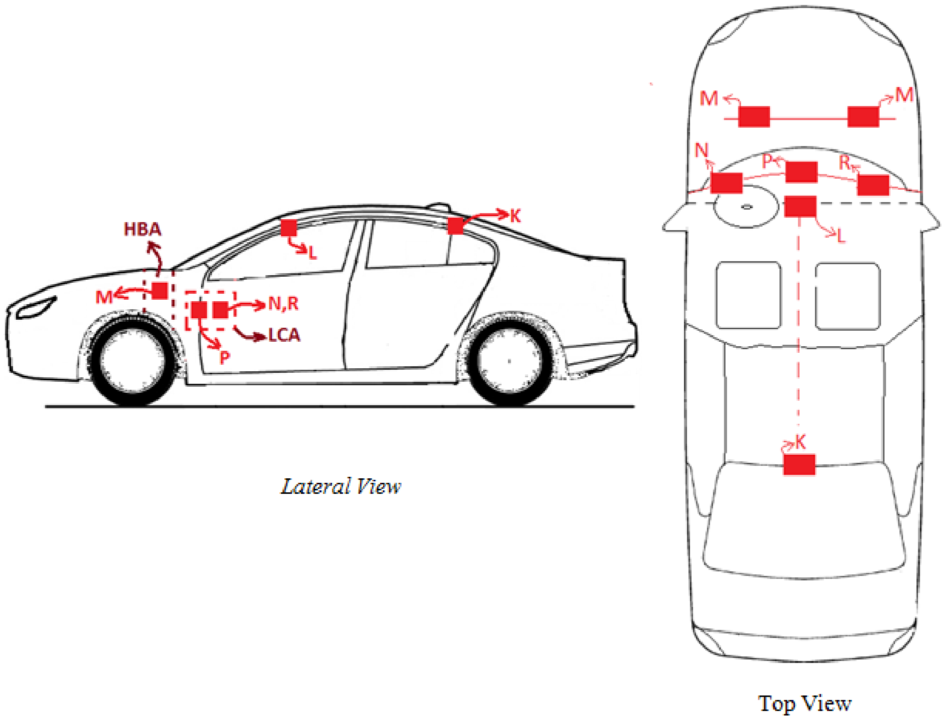

Figure 4.12 Vehicle View for Possible eCall-ECU Mounting Locations

Next, Place-P may be on the middle side of LCA when it is looked at the top view and its height can be nearly the same with Place-N or Place-R in lateral view. On the other hand, Roof-inside places can be at the front side as Place-L; or at the back side of the vehicle as Place-K. Place-L can be defined as; (i) between front mirror and interior rearview mirror at the upper middle side of the front mirror which is in the cab-inside, or (ii) at the intersection point of the upper & middle side of the front mirror and front & middle side of roof-inside. Finally, Place-K is described at the upper & middle side of the rear mirror which has also boundary with the middle & back side of the roof in the cab-inside (middle and back side of the roof-inside). To Understand the Place-K and Place-L, the Figure 4.12 is illustrated purely.

Taking eCall device information -before Figure 4.12 and mounting location possibilities explained after Figure 4.12 -into consideration, App-1/2/3 can be applied to the mounting positions with the alternatives as it is summarized in Table 4.3. The terms in Table 4.3 are; “A: Applicable” and “NA: Not Applicable”.

Table 4.3 Application Type (APP) & Mounting Place Relation

APP/ Mounting Places	Place-M	Place-N	Place-R	Place-P	Place-K	Place-L
APP-1 (Automatic Device)	A	A	A	A	A	A
APP-2 (Manual Device)	A	A	A	A	A	A
APP-3 (Manual Device)	N/A	N/A	N/A	N/A	N/A	A

As a conclusion; eCall device type and its mounting location possibilities are defined in this section. This information enables to create the electrical connection analyze via cost status & signal accuracy analyze including its communication sensitivity in Part 4.7.1.4. Before Part 4.7.1.4, related electrical connections between TCU & eCall control unit and eCall control unit & cellular/GNSS antennas will be explained in Part 4.7.1.3 which also enables the electrical connection to analyze of Part 4.7.1.4.

4.1.7.3 Related Electrical Connections of eCall Equipped Vehicle Systems

ECall control unit in the vehicle system is placed to the mounting location with the reasons which is explained in the last section thanks to the electrical equipment such as antenna connectors, main connectors, electrical wirings. In this section, the connection paths are explained for the possible mounting positions which enable the cost calculations of possible mounting locations in Part 4.7.1.4.

Electrical connection equipment of the eCall control unit have been defined in Part 4.1.2 which explains the connector relations and connection types. The main important point for cost analyze of electrical connections in the mounting location possibilities is the difference of electrical wiring lengths due to the fact that the connectors in both ends (eCall side and TCU side; or eCall side and antenna connection side) and plug-in connectors in the different areas (roof plug-in connectors, hood plug-in connectors etc.) of the vehicle system exist in all cases. Internal connection equipment such as fuses, relays are also used in all application types, so they can be thought as negligible as the cost changes. But, the wiring lengths are changing due to different mounting positions.

In this point of view, the electrical paths of eCall control unit for the possible mounting locations are summarized in Figure 4.13 below.

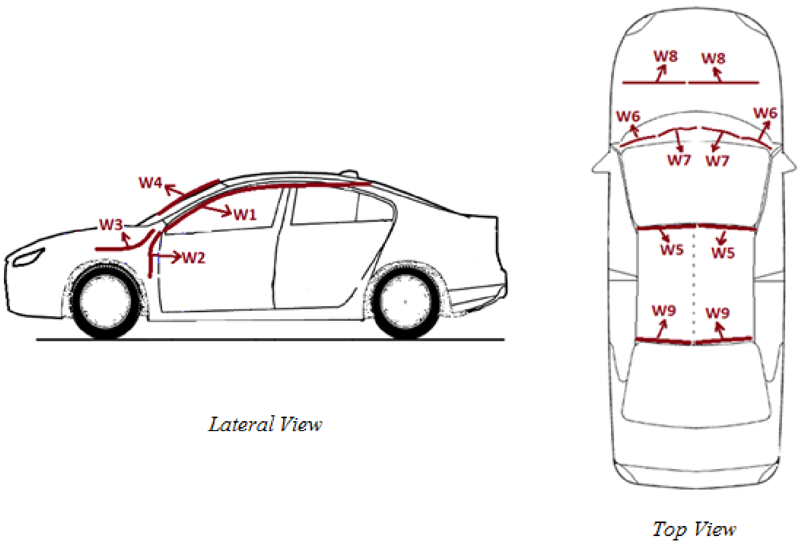

Figure 4.13 Vehicle View for Possible Electrical Paths

‘W1’ Electrical Path explains the connection way of the wiring from the intersection point of rear mirror upper corner & roof outside back corner (at the same side whether both are right side or left side) to the intersection point of front mirror lower corner & end of front corner of front door mirror (at the same side whether both are right side or left side). In Figure 4.13, lateral view explains W1 path at the left side of the vehicle via horizontal dimension in the vehicle coordinates system; so all explained places are thought as at the left side.

‘W2’ electrical path explains the connection way of the wiring of LCA (Lower Cockpit Area). Its beginning is the end of W1 at the front side of the vehicle and its ending is at the LCA area which is explained in Part 4.1.7.1/2. ‘W2’ electrical path is the wiring path at the height (vertical) dimension of the vehicle coordinates system which means from the upper side to lower side of the vehicle structure. In Figure 4.13, lateral view explains; W2 path is at the right side of the vehicle for ‘W4’ relation and it is at the left side of the vehicle for ‘W1’ relation; so all explained places are thought with this logical approach.

‘W3’ electrical path explains the connection way of the HA (Hood Area) and HBA (Hood Battery Area). Its beginning is the end of W1 at the front side of the vehicle and its ending is at the HA area or at the HBA area which is explained in Part 4.7.1.1/2.

‘W3’ electrical path is the wiring paths at the height (vertical) dimension of the vehicle coordinates system and the longitudinal dimension of the vehicle coordinate system. It means height (vertical) coordinates are from the upper side to lower side of the vehicle structure and longitudinal coordinates are from the back side to front side of the vehicle structure. In Figure 4.13, lateral view explains; W3 path is at the right side of the vehicle for ‘W4’ relation and it is at the left side of the vehicle for ‘W1’ relation; so all explained places are thought with this logical approach.

‘W4’ Electrical Path explains the connection way of the wiring from the intersection point of front mirror upper corner & roof outside front corner (at the same side whether both are right side or left side) to the intersection point of front mirror lower corner & end of front corner of front door mirror (at the same side whether both are at right side or left side). In Figure 4.13, lateral view explains W4 path at the right side of the vehicle via horizontal dimension in the vehicle coordinates system. Its usage can be also on the left side. It depends on the design concept.

‘W5’ Electrical Path explains the connection way of the wiring from the intersection point of front mirror upper-middle space & roof outside front-middle space to the intersection point of front mirror upper corner & roof outside front corner (at the same side whether both are right side or left side). In Figure 4.13, top view explains W5 path not only at the right side but also at the left side of the vehicle via horizontal dimension in the vehicle coordinates system; so all explained places are thought with this logical approach.

‘W6’ electrical path explains the connection way of the wiring of LCA (Lower Cockpit Area). Its beginning is the end of W1 at the front side of the vehicle and its ending is at the LCA area which is explained in Part 4.1.7.1/2. ‘W6’ electrical path is the wiring path at the horizontal dimension of the vehicle coordinates system which means from the right side to left side (or left side to right side) of the vehicle structure. In addition, it is configured from the corner sides which are the ends of ‘W1’ and ‘W4’ until the Points N & R for eCall-ECU; or until the Points B & D for TCU. Ecall-ECU points N & R are explained in Figure 4.12 when TCU points B & D are defined in Figure 4.11. In Figure 4.13, top view explains; W6 path is at the right side of the vehicle for ‘W4’ relation and it is at the left side of the vehicle for ‘W1’ relation via horizontal dimension in the vehicle coordinates system.

‘W7’ electrical path explains the connection way of the wiring of LCA (Lower Cockpit Area). Its beginning is the end of W6 electrical path and its ending is the Place-P for eCall-ECU and Place-C for TCU. Place-P (for eCall-ECU) is explained in Figure 4.12 when Place-C (for TCU) is defined in Figure 4.11. In Figure 4.13, top view explains; W7 path is at the right side of the vehicle for ‘W4’ relation and it is at the left side of the vehicle for ‘W1’ relation via horizontal dimension in vehicle coordinates system.

‘W8’ electrical path explains the connection way of the wiring of the HA (Hood Inside Area) or HBA (Hood Battery Area). Its beginning is the end of W3 electrical path and its ending is the place-M for eCall-ECU in HBA and Place-A for TCU in HA. Place-M (for eCall-ECU) is explained in Figure 4.12 when Place-A (for TCU) is defined in Figure 4.11. In Figure 4.13, top view explains; W8 path is at the right side of the vehicle for ‘W4’ relation and it is at the left side of the vehicle for ‘W1’ relation via horizontal dimension in vehicle coordinates system.

‘W9’ Electrical Path explains the connection way of the wiring from the intersection point of rear mirror upper-middle space & roof outside back-middle space to the intersection point of rear mirror upper corner & roof outside back corner (at the same side whether both are right side or left side). In Figure 4.13, top view explains W9 path can be at the right side; or at the left side of the vehicle via horizontal dimension in vehicle coordinates system. ‘W9’ path needs to be used at the left side in the example in Figure 4.13 for W1 path because W1 path is also at the left side.

After the definitions of the electrical paths, the electrical path lengths will be reviewed via real passenger car dimensions in Table 4.4. After the search of nearly 20 different passenger cars with different segments such as A segment, B segment, C segment, CD segment, D segment; minimum and maximum values of the defined electrical path lengths are summarized in Table 4.4. Table 4.4 electrical path lengths will be used in the calculations of electrical wiring lengths and its cost statuses in the analyze of mounting locations of eCall-ECU in Part 4.1.7.4.

Table 4.4 Electrical Paths Minimum & Maximum Lengths Range

Electrical Path	Minimum Value (mm)	Maximum Value (mm)
W1	1250	1750
W2	500	700
W3	400	750
W4	500	1000
W5	500	875
W6	350	500
W7	150	300
W8	450	600
W9	400	750

4.1.7.4 Mounting Locations Review via Communication Accuracy & Cost Status

The analysis of communication quality and cost approach of electrical path is reviewed in this section in three main parts. These are;

1- Communication Signal Quality Rates of eCall-ECU mounting locations (Communication Sensitivity)

2- -TCU & eCall-ECU Distances via electrical paths (Integration of Part 4.1.7.1, Part 4.1.7.2 & Part 4.1.7.3)

-eCall-ECU & Communication Antenna Distances via electrical paths (Integration of Part 4.1.7.2 & Part 4.1.7.3)

-Electrical equipment explanations and wiring price calculations of defined distances

3- Comparison Matrix of Cost Analyses & Communication Sensitivity

- <u>Communication Sensitivity Differences of Possible Mounting Locations of eCall-ECU:</u>

Before explaining the status of this study, the important communication sensitivity factors will be described. After the communication sensitivity factors' (SF) definitions, vehicle application in the study which is eCall ECU mounting location possibilities are reviewed with these factors.

Sensitivity Factor-1 (SF-1): eCall-ECU electrical connections are enabled by the electrical wirings, antenna connectors and main connectors which is explained in Table 4.1 and in Part 4.1.2/3. Electrical wirings will follow the paths which are explained in Part 4.1.7.3. Antenna connectors and main connectors are always in usage whether eCall-ECU is mounted anywhere in the vehicle. In addition, plug-in connectors in the vehicle such as Hood plug-in connectors, roof plug-in connectors and other plug-in equipment such as fuses, relays can be thought as negligible when the price difference of different mounting locations are calculated due to the fact that these equipments are always in usage in the design concepts. As a conclusion of this paragraph, the wiring lengths will decide the cost analysis of electrical connection paths explained in Part 4.1.7.3 and calculated in Part 4.1.7.4.

Sensitivity Factor-2 (SF-2): Communication network in the vehicle communication architecture are changing with respect to required line length and its resistances. In addition, low-speed data sending are generally used for comfort and entertainment functions when the high-speed communication is about chassis and diagnose network in the vehicle systems [199]. Moreover, electrical wiring between the data sending nodes is kept as short as possible in the architecture and number of connections try to be kept to a minimum [198]. In this point of view, eCall-ECU mounting locations will try to have less wiring between eCall-ECU & TCU and eCall-ECU & communication antennas with respect to the electrical equipment in the electrical paths which are explained in Part 4.1.7.3. Especially, the wiring between communication antennas & eCall-ECU decides the communication signal quality in the vehicle system.

Senstivity Factor-3 (SF-3): Communication network requirements need to fit the regulation requirements of eCall communication standards in CEN (European Committee for Standardization), ETSI (European Telecommunication Standards), ISO (International Standards of Organizations) and EN (European Standards). ECall Data transfer is described with the standard ETSI TS 126267 (2009) when its ANSI-C Reference code is enabled with ETSI TS 126268 (2011). Next, conformance testings of eCall data transfer are about ETSI TS 126269 (2009) while data transfer characterization is about ETSI TS and TR 126 969 (2010). Moreover, minimum data set must fit with EN 15722 (2015) when applicational protocols is about EN 16062 (2015). Finally, data registry procedure is applied with ISO/EN 24978 (2009). These are the vehicle applicational procedures of eCall communication. Normally, there exist 7 other regulations for whole eCall infrastructure system requirements, but it is not related to the vehicle side exactly; so they do not contend in this sensitivity factor. This sensitivity factor (SF-3) enables the next sensitivity factor (SF-4) to review communication levels (LSSL & USSL) via eCall mounting locations.

Senstivity Factor-4 (SF-4): Communication network tests include the items of reviews which are Standards/Bands, operating frequency/channels, lower signal spect limit (LSSL) and upper signal spect limit (USSL) [200]. Standards/Bands is the communication level which can be 2G/3G/4G(LTE) when operating frequency can be defined as Low frequency, Mid Frequency, and High Frequency. LSSL and USSL need to be in the range of ETSI standards about the eCall communication explained in SF-3.The output result data (LSSL & USSL in eCall device usage; or LLSL & USSL in eCall device tests) are also defined like frequency definitions such as Low-Level Signal Amplitude, Mid-Level Signal Amplitude, and High-Level Signal Amplitude.

Senstivity Factor-5 (SF-5): Application status of communication antennas usage of eCall-ECU is the important factor to give a command about vehicle eCall system communication with emergency services. Due to this reason, eCall-ECU antennas both cellular antenna (GSM/LTE) and positioning antenna (GNSS) usages need to be defined exactly. eCall-ECU internal cellular modem and GNSS modem can be sufficient in mounting Place-K and Place-L for the eCall communication with emergency services when the accident occurs; because these places are next to the outer surface of passenger car and positioning signals & related cellular signals are obviously forwarded to the emergency services. If the other eCall mounting places are applied (Place-M,N,P,R), internal cellular and GNSS modem will not be sufficient and they must have a relation with the vehicle Cellular communication antenna and Vehicle positioning GNSS antenna which may be on the roof at back side or front side. Mounting Place-K or Place-L can use vehicle cellular and GNSS antenna or their internal cellular and GNSS modems can be sufficient for the cellular communication with emergency services [161]. It depends on eCall control unit design concept and both statuses are analyzed in cost conditions.

Taking all SF's into considerations, eCall device mounting location comparison matrix via only communication sensitivity is defined in Table 4.5.

Table 4.5 ECall Mounting Comparison Matrix via Only Communication Sensitivity

Application Type of eCall ECU	eCall Mounting Location Place	*SF-2 via eCall ECU & TCU	*SF2 via eCall ECU & Cellular/GNSS Antennas	**SF-4 (Thanks to SF-3) (LLSL-ULSL Range)	Communication Sensitivity Command for All SFs (Thanks to SF-5)
App-1/2	Place-K	Long	NA/Short/Mid	High	One of Best Alternative
App-1/2/3	Place-L	Mid	NA/Short/Mid	High	One of Best Alternative
App-1/2	Place-N/R	Low	Long	Low/Mid	Not Preferred Alternative
App-1/2	Place-P	Low	Long	Low/Mid	Not Preferred Alternative
App-1/2	Place-M	Low	Long	Low/Mid	Not Preferred Alternative

*SF-2 Metrics: Long / Mid / Short Wiring Lengths; NA: No Application-No extra wiring.
**SF-4 Metrics: High /Mid /Low Signal Amplitudes.

Table 4.5 result is not the final conclusion due to the requirement of cost analyze which will be reviewed in Part 4.1.7.4. In Table 4.5, Place-K and Place-L have the best options for the communication signal qualities. On the other hand, Places-M, N, P and R signal quality is lower than Places-K and Place-L due to the SF-2 wiring lengths and SF-4 signal amplitudes. These results will be combined with the electrical cost results of Part 4.1.7.4 and Total results to give a comment about the eCall device mounting locations will be explained in Part 4.1.7.4.

- <u>Electrical Path Distances & Price Differences of Mounting Locations of eCall-ECU</u>

Electrical Path analyzes for eCall ECU is enabled by the review of eCall-ECU relation with TCU and cellular & GNSS antennas as it is shown in the electrical interface in Figure 4.14.

This configuration in Figure 4.14 enables to understand that the electrical paths are reviewed via 3 distances. These are; (i) the distance between eCall ECU & Cellular Antenna, (ii) the distance between eCall ECU & GNSS Antenna and (iii) the distance between eCall ECU & TCU.

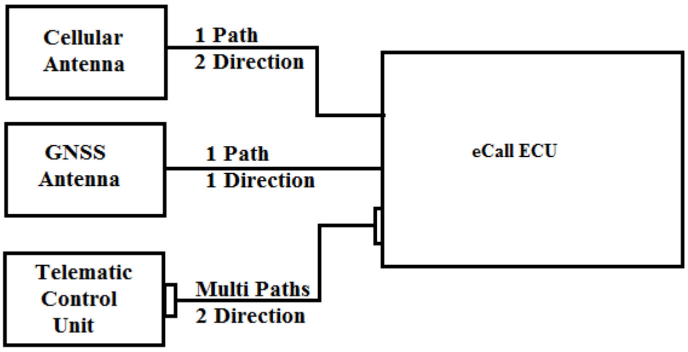

Figure 4.14 Vehicle Electrical Interface via eCall Structure

The defined Places for eCall in Figure 4.12 are analyzed via electrical paths of Figure 4.13 for these three connections of Figure 4.14. The connectors in the electrical equipment in Figure 4.14 are not joined to the calculation matrix due to the reason which is emphasized in Part 4.1.2/3. The unit price of wiring is put into the calculation between 0,24 € per meter and 0,26 € per meter [202]. The eCall ECU connection with TCU & vehicle system is assumed as 18 Pin connection; so Multipath definition in Figure 4.14 is thought as 18 wirings for TCU [203]. Its pin requirements can increase or decrease with respect to the eCall device design concept which is also emphasized in Table 4.1.

‘Place-K’ eCall ECU Electrical Path Alternatives & Its Cost Status:

When Place-K is applied as the mounting location of eCall-ECU, cellular and GNSS antennas can be at Place-K or Place-L; and TCU can be at the places; A,B,C or D. The Place-K cost matrix is reviewed in Table 4.6.

Table 4.6 Place-K eCall ECU Mounting Location Cost Matrix

eCall ECU Place	TCU Place	Cellular/GNSS Antenna Place	Wiring Paths in Usage	Total Wiring Length (meter)	Unit Price of the Wiring (€/meter)	Net Cost Result (€)
K	A	K	W9,W1,W3	36,9 to 58,5	0,24 to 0,26	8,8 to 15,2
	A	L	W9,W1,W3,W5,W9,W1-W4	40,2 to 63,25		9,6 to 16,4
	B	K	W9,W1,W2,W6	45 to 66,6		10,8 to 17,3
	B	L	W9,W1,W2,W6,W5,W9,W1-W4	48,3 to 71,35		11,6 to 18,5
	C	K	W9,W1,W2,W6, W7	47,7 to 72		11,4 to 18,7
	C	L	W9,W1,W2,W6,W7, W5,W9,W1-W4	51 to 76,75		12,2 to 19,9
	D	K	W9,W1,W2,W6	45 to 66,6		10,8 to 17,3
	D	L	W9,W1,W2,W6,W5,W9,W1-W4	48,3 to 71,35		11,5 to 18,5

Table-Note: Blue writing is the wiring of eCall-ECU & Antennas; when black writing is the wiring of eCall-ECU &TCU in wiring path in usage.

As it is shown in Table 4.6, eCall-ECU at Place-K can have the cost range between 8,8 € and 19,9 €.

‘Place-L’ eCall ECU Electrical Path Alternatives & Its Cost Status:

When Place-L is applied as the mounting location of eCall-ECU, cellular and GNSS antennas can be at Place-K or Place-L; and TCU can be at the places; A,B,C or D. The Place-L cost matrix is reviewed in Table 4.7.

Table 4.7 Place-L eCall ECU Mounting Location Cost Matrix

eCall ECU Place	TCU Place	Cellular/GNSS Antenna Place	Wiring Paths in Usage	Total Wiring Length (meter)	Unit Price of the Wiring (€/meter)	Net Cost Result (€)
L	A	K	W5,W4,W3,W5,W9,W1-W4	13,2 to 22,2	0,24 to 0,26	3,2 to 5,7
	A	L	W5, W4, W3	25,2 to 47,3		6 to 12,3
	B	K	W5,W4,W2,W6,W5,W9,W1-W4	36,6 to 60,1		8,7 to 15,6
	B	L	W5,W4,W2,W6	33,3 to 55,3		7,9 to 14,4
	C	K	W5,W4,W2,W6,W7,W5,W9,W1-W4	39,3 to 65,5		9,4 to 17
	C	L	W5,W4,W2,W6,W7	36 to 60,7		8,6 to 15,8
	D	K	W5,W4,W2,W6,W9, W5, W1-W4	36,6 to 60		8,7 to 15,6
	D	L	W5,W4,W2,W6,	33,3 to 55,3		7,9 to 14

Table-Note: Blue writing is the wiring of eCall-ECU & Antennas; when black writing is the wiring of eCall-ECU &TCU in wiring path in usage.

As it is shown in Table 4.7, eCall-ECU at Place-L can have the cost range between 3,2 € and 17 €.

‘Place-N/R’ eCall ECU Electrical Path Alternatives & Its Cost Status:

When Place-N/R is applied as the mounting location of eCall-ECU, cellular and GNSS antennas can be at Place-K or Place-L, and TCU can be at the places; A,B,C or D. The Place-N/R cost matrix is reviewed in Table 4.8.

Table 4.8 Place-N/R eCall ECU Mounting Location Cost Matrix

eCall ECU Place	TCU Place	Cellular/GNSS Antenna Place	Wiring Paths in Usage	Total Wiring Length (meter)	Unit Price of the Wiring (€/meter)	Net Cost Result (€)
N/R	A	K	W2,W6,W3,W9,W1,W2,W6	27,5 to 42,5	0,24 to 0,26	6,6 to 11
	A	L	W2,W6,W3,W5,W4,W2,W6	26,2 to 41,2		6,3 to 10,7
	B	K	W9,W1,W2,W6	5 to 7,4		1,2 to 1,9
	B	L	W5,W4,W2,W6	3,7 to 6,15		0,8 to 1,5
	C	K	W7,W9,W1,W2,W6	7,7 to 12,8		1,8 to 3,3
	C	L	W7,W5,W4,W2,W6	6,4 to 11,5		1,5 to 3
	D	K	2W7,W9,W1,W2,W6	10,4 to 18,2		2,4 to 4,7
	D	L	2W7,W5,W4,W2,W6	9,1 to 16,9		2,1 to 4,4

Table-Note: Blue writing is the wiring of eCall-ECU & Antennas; when black writing is the wiring of eCall-ECU &TCU in wiring path in usage.

As it is shown in Table 4.8, eCall-ECU at Place-N/R can have the cost range between 0,8 € and 11 €.

<u>‘Place-P’ eCall ECU Electrical Path Alternatives & Its Cost Status:</u>

When Place-P is applied as the mounting location of eCall-ECU, cellular and GNSS antennas can be at Place-K or Place-L; and TCU can be at the places; A,B,C or D. The Place-P cost matrix is reviewed in Table 4.9.

Table 4.9 Place-P eCall ECU Mounting Location Cost Matrix

eCall ECU Place	TCU Place	Cellular/GNSS Antenna Place	Wiring Paths in Usage	Total Wiring Length (meter)	Unit Price of the Wiring (€/meter)	Net Cost Result (€)
P	A	K	W2,W6,W3,W7,W9,W1,W2,W6,W7	30,5 to 48,5	0,24 to 0,26	7,3 to 12,6
	A	L	W2,W6,W3,W7,W5,W4,W2,W6,W7	29,2 to 47,2		7 to 12,2
	B	K	W7,W9,W1,W2,W6,W7	8 to 13,4		1,9 to 3,4
	B	L	W7,W5,W4,W2,W6,W7	6,7 to 12,1		1,6 to 3,2
	C	K	W7,W9,W1,W2,W6	5,3 to 8		1,3 to 2
	C	L	W7,W5,W4,W2,W6	4 to 6,7		0,9 to 1,7
	D	K	W7,W9,W1,W2,W6,W7	8 to 13,4		1,9 to 3,4
	D	L	W7,W5,W4,W2,W6,W7	6,7 to 12,1		1,6 to 3,2

Table-Note: Blue writing is the wiring of eCall-ECU & Antennas; when black writing is the wiring of eCall-ECU &TCU in wiring path in usage.

As it is shown in Table 4.9, eCall-ECU at Place-N/R can have the cost range between 0,9 € and 12,6 €.

‘Place-M’ eCall ECU Electrical Path Alternatives & Its Cost Status:

When Place-M is applied as the mounting location of eCall-ECU, cellular and GNSS antennas can be at Place-K or Place-L, and TCU can be at the places; A,B,C or D. The Place-M cost matrix is reviewed in Table 4.10.

Table 4.10 Place-M eCall ECU Mounting Location Cost Matrix

eCall ECU Place	TCU Place	Cellular/GNSS Antenna Place	Wiring Paths in Usage	Total Wiring Length (meter)	Unit Price of the Wiring (€/meter)	Net Cost Result (€)
M	A	K	W9,W1,W3	4,1 to 6,5	0,24 to 0,26	0,9 to 1,7
	A	L	W5,W4,W3	2,8 to 5,2		0,7 to 1,4
	B	K	W2,W6,W3,W9,W1,W3	26,6 to 41,6		6,4 to 10,8
	B	L	W2,W6,W3,W5,W4,W3	25,3 to 40,3		6,1 to 10,5
	C	K	W3,W2,W6,W7,W9,W1,W3	29,3 to 47		7 to 12,2
	C	L	W2,W6,W3,W7,W5,W4,W3	28 to 45,7		6,7 to 11,9
	D	K	W3,W2,W6,W9,W1,W3	26,6 to 41,6		6,4 to 10,8
	D	L	W3,W2,W6,W5,W4,W3	25,3 to 40,3		6 to 10,5

Table-Note: Blue writing is the wiring of eCall-ECU & Antennas; when black writing is the wiring of eCall-ECU &TCU in wiring path in usage.

As it is shown in Table 4.10, eCall-ECU at Place-M can have the cost range between 0,7 € and 12,2 €.

As a result of the tables, they enable to see the cost range comparison of eCall-ECU locations as shown below in Table 4.11.

Table 4.11 eCall-ECU Places & Electrical Path Cost Relations

eCall ECU Place	Minimum Cost (€)	Maximum Cost (€)
Place-K	8,8	19,9
Place-L	3,2	17
Place-N/R	0,8	11
Place-P	0,9	12,6
Place-M	0,7	12,2

The cost result discussion for the mounting location places is not emphasized in this section. It is analyzed in the next section with the combination of this Table (Table

4.11) and Table 4.5 which enables the pure discussion about eCall-ECU mounting locations not only for cost status but also for communication sensitivity.

- <u>Total Result: Comparison Matrix of Cost Analayse & Communication Sensitivity</u>

Communication Sensitivity is analyzed in Part 4.1.7.4 which has the results in Table 4.5 and electrical cost differences of mounting locations of eCall-ECU is investigated in Part 4.1.7.4 which has the cost results in Table 4.11.When the integration of these two result tables (Table 4.5 & Table 4.11) are enabled, new Table with the results is created as below in Table 4.12.

Table 4.12 Comparison Matrix of eCall-ECU Possible Mounting Locations

Application Type of eCall ECU	eCall Mounting Location Place	*SF-2 via eCall ECU & TCU	*SF2 via eCall ECU & Cellular / GNSS Antenna(s)	**SF-4 (Thanks to SF-3) (LLSL ULSL Range)	Communication Sensitivity Command for for All SFs (Thanks to SF-5)	***Min. Cost Status (€)	***Max. Cost Status (€)
App-1/2	Place-K	Long	NA/Short/Mid	High	One of Best Alternative	8,8	19,9
App-1/2/3	Place-L	Mid	NA/Short/Mid	High	One of Best Alternative	3,2	17
App-1/2	Place-N/R	Low	Long	Low/Mid	Not Preffered Alternative	0,8	11
App-1/2	Place-P	Low	Long	Low/Mid	Not Preffered Alternative	0,9	12,6
App-1/2	Place-M	Low	Long	Low/Mid	Not Preffered Alternative	0,7	12,2

*SF-2 Metrics: Long / Mid / Short Wiring Lengths; NA: No Application

**SF-4 Metrics: High /Mid /Low Signal Amplitude

*** Min.: Minimum; Max.: Maximum

According to the Final Comparison Matrix in Table 4.12 above, the best signal quality is enabled in Place-K and Place-L when the best price is enabled in Place-N and Place-R.

When <u>the optimal situation</u> is created via high signal quality and less price; Place-L can be the optimal solution for the eCall device mounting location; because its cost status can decrease until 3,2 € and its signal quality is enabled as high quality for APP-1 and APP-2. <u>APP-3 has a unique alternative</u> as Place-L in this review.

The second option of APP-1/2 of eCall-ECU mounting location can be Place-N or Place-R due to the fact that; its maximum cost difference with the other two places such as Place-P and Place-M is nearly 1 € lower when the minimum cost side is so near with each other. All places at HA, HBA or LCA has the low or mid signal quality when it is compared with the roof-side places such as Place-L and Place-K.

The worst option of APP-1/2 of eCall-ECU mounting location can be the Place-K; because its minimum cost is too high (8 €) when the other minimum cost rates (0,7 / 0,8 / 0,9 € and 3,2 €) are smaller than this rate. But, if the application is applied to the luxury passenger cars or passenger cars which includes full accessories, this place can be used because its communication & positioning signal quality rate will be more important than its prices for these types of automobiles; and communication & positioning signal quality of this place (Place-K) is higher than other four places (N, R,M, P).

4.1.8 Vehicle Application: Cost Reduction Strategy of eCall Equipped Vehicle Systems

Nowadays, the vehicles are produced with the multitude of sensors and electronic equipment [198]. The electrical and electronic parts in the vehicle systems cause the vehicle having high-cost rates [75]. These rates are tried to be decreased. The possible cost reduction items can be created by the types of cost reductions.

The cost reduction items in the vehicle systems can be enabled in the periods in Figure 4.15 below. In figure 4.15, RI means the Research and Innovation period and PD means the Product development. While PP defines the product (component) production by Tier-1 and Tier-2 suppliers, VP explains the vehicle production. Finally, AT means the aftermarket product strategy.

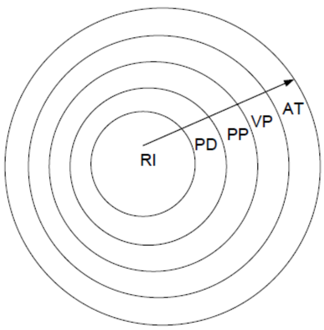

Figure 4.15 Cost Reduction Steps in Automotive OEMs

In this study, the cost reduction steps in Figure 4.15 are applied with the items as;

- ➢ Application-1: Device GNSS and Cellular Antenna Usage (PP item of Figure 4.15).
- ➢ Application-2: eCall device connector pin-outs usage (PD & RI items of Figure 4.15).
- ➢ Application-3: Product and Company Remark on the device (PD & RI items of Figure 4.15).
- ➢ Application-4: eCall device main connector usage (PD & RI items of Figure 4.15).
- ➢ Application-5: eCall device positioning in the vehicle (VP item in Figure 4.15).
- ➢ Application-6: eCall system aftermarket preparation (vorrüstung in German) (AT item in Figure 4.15).

The application items above are analyzed in this study whether the cost reductions can be useful to advise for the automotive OEMs.

This part is the development side of the article which is the integration of Part 2 and Part 3 by Apps of Figure 4.15. In the explanations, the piece price is defined without any volume of vehicle, vehicle type and a number of connections. The savings due to the APPs are mentioned for only piece price per connection.

<u>Application-1: eCall Device GNSS and Cellular Antenna Usage (PP item of Figure 4.15)</u>

Ecall equipped vehicles need to have communication with the GNSS positioning antenna and cellular antenna to have a connection with public safety answering points when the accident occurs. The GNSS and cellular antennas are defined in the vehicle architecture in Figure 4.6

If the GNSS antenna is used by eCall device on behalf of vehicle GNSS antenna as it is emphasized in Figure 4.6, it can cause to have nearly 10 € cost difference as a piece price [204].

If the cellular antenna is used by eCall device on behalf of vehicle cellular antenna as it is emphasized in Figure 4.6, it can cause to have nearly 7 € cost difference as a piece price [201].

On the other hand, GNSS and cellular antennas can be the part of eCall device which is embedded to eCall system can have nearly 12 € piece price difference which is the cost down item due to the fact that the GNSS & cellular antennas' usage externally does not exist (see Figure 4.5). It can be adapted inside the eCall device and it is assumed that antennas are inside of the eCall device as it is shown in the architecture of eCall device (68 & 69 on behalf of 65, 66 and 67). The device can have good communication rates if it's mounted correctly into the vehicle. The cost down rate may have a maximum value as 12 € [204]. If the vehicle is using the antennas for different vehicle applications without eCall, the cost down status can be thought as nearly 5 € with respect to the connection with splitter, antenna and wiring prices.

<u>Application-2: eCall device connector pin outs usage (PD & RI items of Figure 4.15)</u>

In vehicle applications, there exist three main usages of connector pin-outs materials. These are tin, silver and gold material usages [202, 203]. The requirements enable the suppliers & Automotive OEMs to use these materials as connector pins. Tin material connectivity and signal quality is lower than silver. The same property of the silver material is lower than gold material [163]. Gold material is more expensive than silver material and the tin material is cheaper than silver material.

Taking this information into consideration, it is a logical approach to choose the gold material in the pin-out selection to have a good quality. But, the cost reduction topics due to high costs of the vehicles cause to change the gold material with the other materials if the design is completed with gold pin-outs. On the other hand, sometimes there can be the communication problems in tin pin-outs or its lifetime is shorter than the others. In this point of view, silver pin-outs can be the optimal option to choose the design concept. This pin-out material information can be applied not only for Fakra Connectors but also for main connectors.

The piece price change between gold, silver and tin material can be thought as 0.1 € per connection in a vehicle [164]. According to vehicle volume and number of connection, cost down status can be increased.

<u>Application-3: Product and Company Remark on the device (PD & RI items of Figure 4.15)</u>

Normally, the whole electrical and electronic device types in the vehicle systems are having the remark as part number and OEM company name on the component; but, it depends on company decide whether the product includes these remarks or not.

In this point of view, the variations of remarkable product status can be as below:

- OEM can desire product number and OEM name from Tier-1

- OEM can desire product number from Tier-1 when there is no company remark.
- OEM can desire nothing from Tier-1 which means there is no remark.

If OEM can desire only part number, there can be nearly 0.25 € cost decrease per piece price [161]. On the other hand, there can be nearly 0.5 € cost decrease per piece price if the OEM can desire nothing in the product remark.

<u>Application-4: eCall device main connector usage (PD & RI items of Figure 4.15)</u>

The device connections can be enabled by three or four connectors in eCall device. These are Fakra connector for GSM Antenna, Fakra Connector for GNSS Antenna and Main Connector for Vehicle signal connections [163]. The main connector can be applied to one main connector or two parts of the main connector. As it is investigated in USCAR (2016) connector requirements, if the numbers of pins are high in the connector system, it can be used with the sections including the main connector as two parts. The reason of using more than one section in the main connector can be;

- Protection of pin out-breakings
- Protection of Connector external surface
- Protection of pin-out holes

When the connector is getting out of its place or is setting into the place, the problems which are mentioned as protections above can occur if the connector is too long when it has lots of pin-outs.

Taking this information into consideration, main connector cost down rate can be nearly 1 € if the one piece of the main connector is compared with two piece of main connectors.

<u>Application-5: eCall device positioning in the vehicle (VP item in Figure 4.15):</u>

The eCall device can be positioned in different places in the vehicle. The example positioning in the passenger car is defined in Figure 4.12.

Point-M is in HBA area which means the Hood Battery area; when N, R, P points on the back side of the lower cockpit (LCA; Lower cockpit area). Moreover, L and K points are in the roof-inside area which can be the setup place of the eCall device. The wiring and connector piece price calculations are processed by the author in the places. The calculations include wiring and connector usage and the piece price differences between the mounting locations are defined in Table 4.12. The calculated cost difference comes from; (i) the distance between eCall device and telematics control unit of the vehicle, and (ii) the difference between communication antennas and eCall device.

In Table 4.12; not only the signal amplitude but also cost status is explained by the author calculation and measurements. It shows that the cost reduction due to mounting places can be up to 18 € via mounting location. If the high amplitude of signal range is preferred, the cost reduction can be up to nearly 16 €.

Application-6: eCall system aftermarket preparation (vorrustung in German) (AT item in Figure 4.15)

EU 2015/758 is a European Union regulation which has been published in April, 2015 and its start date of application will be March, 2018 for Passenger Cars and Light Duty vehicles [2]. Its Heavy Duty applications will also start near to this period. It defines all passenger cars and light duty vehicles will be equipped with emergency call equipment at the end of March, 2018; while emergency services in the country infrastructures will be ready for the new public safety answering point system with the start date of October, 2017.

Due to the explanation above, eCall system in the vehicle can be an obligation or not. If the system is not an obligation such as Heavy-duty vehicles, it can be applied to the vehicle as aftermarket product. If the eCall system is aftermarket product for the vehicle, it has wiring connections, mating connectors, communication tools such as GNSS antenna, cellular antenna; but it does not have eCall device including a control unit and measurement unit.

In this point of view, eCall preparation (vehicle wirings, mating connectors etc.) enables to have cost reduction nearly between 100€ and 150 € without eCall device. It is thought that the vehicle owner can set up which eCall device prefers at the outside market.

This paper advises the optimal solution of next-generation architecture of vehicle applications. Its architecture is described in Figure 4.2 and cost study results are explained in Figure 4.12, Figure 4.15 and in Table 4.12. Its optimal solution can be to use as ; (i) internal GNSS and cellular Antennas inside of the eCall device without vehicle antenna in Application-1; (ii) eCall device connector pin-outs as silver pin-outs in Application-2; (iii) eCall device using without company and product remark in Application-3; (iv) eCall device one main connector in Application-4; (v) eCall device mounting in lower cockpit in Application-5; (vi) Aftermarket strategy within whole preparation without eCall device in Application-6.

4.2 Ecall System Infrastructure-1: Public Safety Answering Points (PSAPs)

Public safety answering points which have the capability of receiving accident data sets are built by service providers and are built with required-equipments for infrastructure and network [124]. Its infrastructure includes workstations, related office equipment, network and wireless link structures. The Workstation is the working-space that includes ancillary and telephony equipment, emergency back-up and call management softwares. Network structure describes frame relay network, its equipment, and terminal lines. Moreover, wireless side of the network is capable of its equipment, service charges and database.

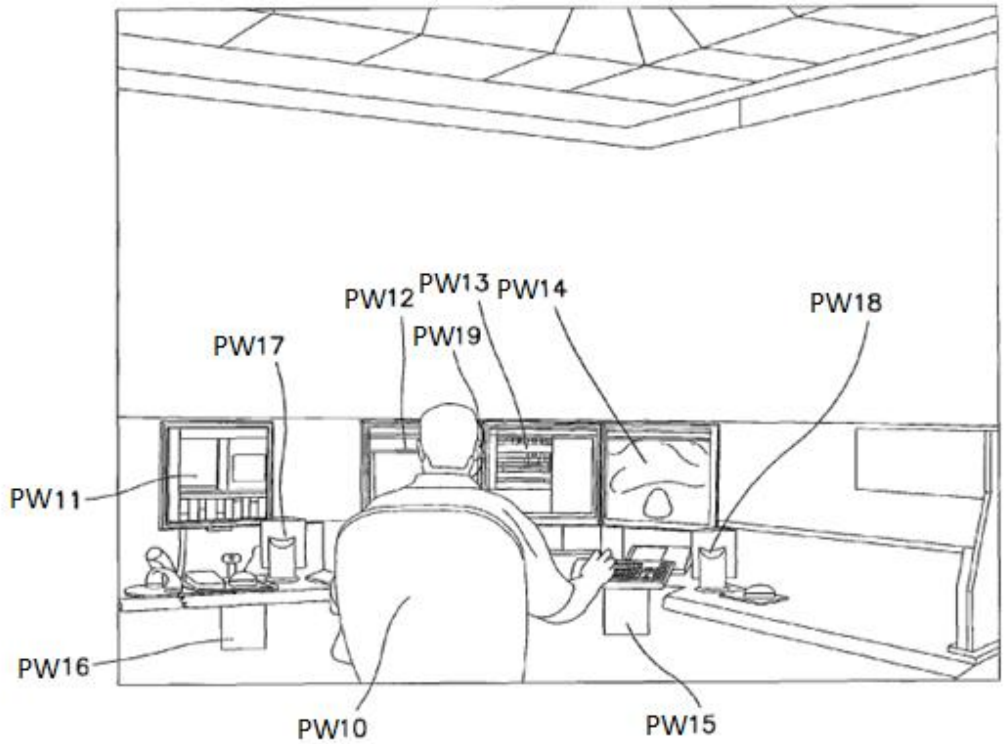

Figure 4.16 PSAP-Worker and Working Enviroment [87]

In a typical PSAP service in Figure 4.16, there exist the computer monitors (PW11, PW12, PW13, PW14) and they are tried to be designed the responsible person does not see the other responsible persons to increase attention to the services. The number of monitors can be changed station to station via its usage and design concepts. The monitors are used to control the computer-aided response units (PW15) such as location, identities of the situations including its own software programmes. The response-console (PW16) is the console of the monitor (PW-11) which is used to define the accident or problem with the response unit and its call management software programme including disposal and display information. Each service person has a unique speaker system (PW17, PW18) to hear the communication talk groups. Moreover, the headset (PW19) enables the service person to work with both hands without any hold of phone head. It enables the degree of freedom to the service responsible person whether writing something and using the computer during the phone conversation which means the usage of two hands free.

PSAP types have been described in the Part 3.2 "The whole generic eCall Structure After eCall equipped vehicle regulation". According to PSAP types, properties of PSAP workers can be different. Operators in PSAPs as it is figured in Figure 4.16 can be only call-taker or it can be a talented person as providing not only call taking but also dispatching processes. Emergency number operator is a call-taker who is in progress of accident on the map with respect to data transmission of eCall system [87]. Accident data are sent by them to the related rescue services with its own answering tools such as management software, traffic information.

4.2.1 PSAP Call Taker Education Levels

Call takers in PSAP services can have three types of service persons. These are;

- Highly Trained PSAP Call Takers
- Middle Trained PSAP Call Takers
- Low Trained PSAP Call Takers

Highly trained PSAP Call Takers can give responses to the emergency callings and can make the dispatches to the rescue service vehicles.

Middle trained PSAP Call Takers can take emergency callings and forward them to the rescue stations where the dispatches to the rescue vehicles are made. This type of service persons can support the dispatch process if the rescue station needs, which means they can have the dispatch ability to the rescue service vehicles, but they are not making dispatch to the rescue vehicles.

Low trained PSAP Call Takers can only take the calls and ask which rescue service is needed (classify calls) to the emergency callings and they forward it to the related rescue station(s). Low trained Call takers do not have the ability and do not make dispatch to the rescue service vehicles.

4.2.2 PSAP Call Taker Education Levels in EENA Architectures

The European Emergency Number Association Current Architectures are defined with respect to the PSAP Call takers :

- In EENA, Model-1 (current statuses of Case Study-4 and Case Study-5 in Chapter-7); the PSAP call-takers are the rescue service station persons because of the fact that there is no different 112 PSAP service station. 112 PSAP is set up in one of emergency rescue service station and PSAP calls are managed by this emergency rescue service persons. The rescue service person in the rescue service which has 112 PSAP are highly trained when the other two rescue service persons are low trained or middle trained.
- In EENA, Model-2 (current status of Case Study-3 in Chapter-7); the PSAP call-takers are low trained who gives an answer to the emergency callings and they do not make any dispatch process. Next, 112 PSAP call takers are only asking (classify calls) which rescue services the emergency call is needed and they forward the emergency calling to the related rescue service(s). They do not support the dispatchers or they do not have an ability about dispatch process to rescue service vehicles.
- In EENA, Model-3; the PSAP call-takers are low trained and have the same properties as EENA, Model-2. Additionally, the emergency service persons are supporting the PSAP call takers in some cases and the classified calls in 112 PSAP are forwarded to the rescue service station with parallel dispatch.
- In EENA, Model-4; (current statuses of Case Study-2 in Chapter-7); the PSAP call takers are middle trained. They are giving responses to the emergency callings and forwarded to the emergency rescue service units in the control room/building.They can support the rescue service dispatchers in some cases and they have an ability about dispatch process to rescue service vehicles.
- In EENA, Model-5; (current statuses of Case Study-1 in Chapter-7); the PSAP call takers are highly trained. They are giving responses to the emergency callings and they are making dispatches to the rescue service vehicles. In addition, they are talented persons who are associated with mapping process,

computer-aided dispatch, technical support to the issues due to being only unique service for the emergency callings which means there is no rescue service station for the dispatch process to the rescue service vehicles.

- In EENA, Model-6; PSAP call takers are the same as EENA, Model-2 or EENA Model-3. Additionally, their PSAP connection architecture is interconnected. The PSAPs in the same region are connected to each other in the same region.

4.2.3 PSAP Call Taker Received Data About the Accidents

112 PSAP call takers have the user interface screen as it is shown in Figure 4.17 [32]. This is one of the example GUI (Graphical User Interface) of 112 PSAPs. After the eCall equipped vehicle regulation in 2018, the same interfaces can be also used in Manual or Auto eCall PSAPs.

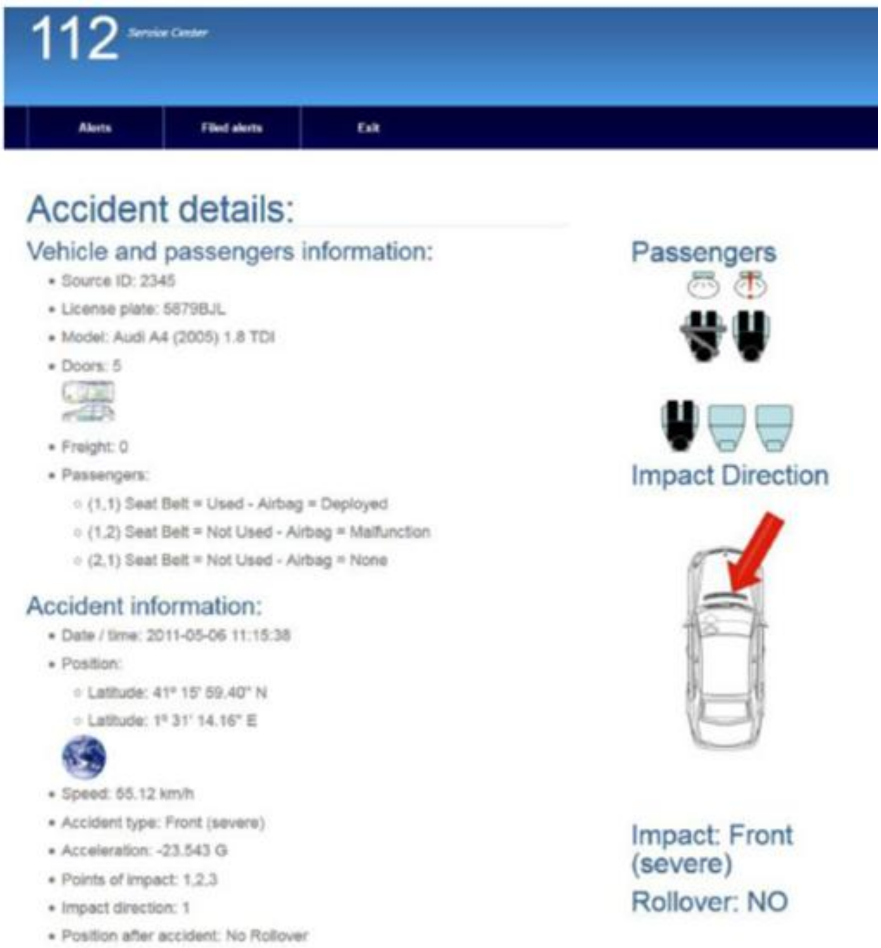

Figure 4.17 User Interface Part of Service Worker Computer [32]

As it is shown in the Figure 4.17, the PSAP call taker has an information about the accident of the vehicle, passengers, vehicle, road and impact statuses. Impact factor which has been explained in Part 4.15 is important to understand the accident severity. Next, inside of the vehicle with the information of seatbelt, driver and passenger locations and airbag openings give the data whether the accident causes an injury types such as slight injury or severe injury with the data support of impact factor. In addition to them, accident minimum data set includes accident time, accident type, accident place with its coordinates and name of the road. The vehicle registry information which means the vehicle is firstly sold in order to give the first answer to the emergency service in the same language is another important factor.

4.2.4 Details of PSAP Infrastructures

PSAP Infrastructure includes the workstations and its places; network infrastructures such as frame relay network, telephony services, frame relay equipment, OEM terminal line; computer software such as mapping software, data layers; power supply modules; wireless equipment.

One of 112 PSAP includes the infrastructure parts as Table 4.13.

Table 4.13 Infratsructure Parts of PSAP or Rescue Service

Eq. Type-1	Eq. Type-2	Eq. Type-3	Eq. Type-4
Administrative Part	Software Equipments	PSAP Facility Circuits	Wireless Equipments
Eq. Type-5	Eq. Type-6	Eq. Type-7	Eq. Type-8
Customer Premise Equipment	Network Equipments	Uninterrupted Power Supply Modules Eq.	Whole Parts Maintenance Equipments

-Eq. Type-1 in Table 4.13 is the administrative part including costs about PSAP persons which has the unit costs of callings per persons, computer-aided dispatch callings per persons, the labor cost of persons, working hour per persons, public educations per persons, memberships per persons, conference and professional developments per persons.

-Eq. Type-2 in Table 4.13 is the software equipments including mapping software, MSAG (master street address guide) software, GIS (geographical information system) data layers, call management software with a voice recorder.

-Eq. Type-3 in Table 4.13 is PSAP Facility circuits including eCall events, admin telephony services, facilities, its upgrades, and replacements.

-Eq. Type-4 in Table 4.13 is wireless equipment including accuracy testing requirements, service charges, database charges and pseudo automatic number identification charges.

-Eq. Type-5 in Table 4.13 is customer premise equipment including telco tax processes and workstation processes which has a content of telephony equipment, computer-aided dispatch units, call loger ancillary equipment and backup with power capability.

-Eq. Type-6 in Table 4.13 is network equipment including frame relay network, admin services, telephony services, frame relay equipment, frame relay monthly access and terminal lines.

-Eq. Type-7 in Table 4.13 is uninterrupted power supply modules.

-Eq. Type-8 in Table 4.13 is the maintenance requirements of these 7 Eq. Types.

4.2.5 Details of PSAP İnfrastructures in EENA Current Architectures

Taking these parts into consideration, the infrastructural differences of PSAPs comes from the PSAP usages in the architectures. There are the different cases for the emergency service infrastructures at the current statuses of EENA architectures as below:

- If the PSAP is used as a different station from rescue services and there is no parallel dispatch; it does not need any additional infrastructural equipment. For instance, EENA,Model-2 has the 112 PSAP and rescue service stations differently; so its 112 PSAP does not include any extra equipment and it has all parts of Table 4.3.
- If one of the rescue services is used as 112 PSAP, this PSAP will have extra infrastructural equipment and it will have more PSAP persons. For instance, Model-1 has a 112 PSAP in one of the rescue service stations; so its rescue

service including 112 PSAP which has extra PSAP equipment. The other two rescue services do not include any extra equipment.

- If the PSAP is used as a different station from rescue services and 112 PSAP makes a parallel dispatch to the rescue services; it needs any additional infrastructural requirements. For instance, EENA,Model-3 has the 112 PSAP and rescue service stations differently and it has a parallel dispatch structure from 112 PSAP to rescue service stations; so its Eq. Type-1 and Eq.Type-2 will be expensive than EENA, Model-2 structure.
- If the PSAP is used in the same control room/building with rescue services; infrastructural requirements will have differences. For instance, EENA, Model-4 has control room/building structure. It's Eq. Type-3, Eq. Type-5 and Eq. Type-6 are cheaper due to being in the same building with rescue service units.
- If the PSAP is used as one unit not only for giving responses to the emergency callings but also for making dispatches to the rescue service vehicles without any rescue services; infrastructural requirements will be different. For instance, EENA, Model-5 has only 112 PSAPs for emergency callings and it has not any rescue service station for dispatch process. 112 PSAPs makes both processes. It's Eq. Type- 1 is higher due to cad (computer aided dispatches) and time dispatch (wanted issues etc.) process and its Eq. Type-3 is expensive due to having more workstation costs. On the other hand; its Office Costs and Facility costs in Eq. Type-3 is cheaper than the systems which have rescue services such as EENA, Model-1, EENA, Model-2, EENA, Model-3. It's infrastructural Eq. Type-4, Eq. Type-6, Eq. Type-7 and Eq. Type-8 are also cheaper than the other architectures. As a conclusion, this case is not only cheaper but also better infrastructural system.
- If the PSAP is used as a different station from rescue services and 112 PSAPs are connected to each other in the same region, their Eq. Type-6 and Eq. Type-8 requirements will be more expensive than the other structures. For instance, EENA, Model-6 has this type of structure and its Eq. Type-6 and Eq. Type-8 requirements are more expensive than the EENA, Models.

4.2.6 Details of PSAP İnfrastructures after eCall equipped Vehicle Regulations in 2018

Explained differences in EENA Architectures via PSAP Infrastructures will be updated after eCall equipped vehicle regulations. After the regulations, there will be two additional units as Manual eCall PSAP and Auto eCall PSAP which has been explained in Part 3.2 and its details will be expanded in Part 5.2. These new PSAPs cause to update or modify the current EENA, Architectures. Their PSAP Infrastructure details in Part 4.2.5 and in Table 4.13 is changing the items below:

- Manual eCall PSAP creates new costs between Eq. Type-1 and Eq. Type-8 and Auto eCall PSAP create new costs between Eq. Type-1 and Eq. Type-8.
- If the eCall PSAPs are integrated and used as a different unit they create new costs between Eq. Type-1 and Eq. Type-8.
- If the Manual eCall PSAP or Auto eCall PSAP is integrated to the 112 PSAP, Integrated PSAP including 112 PSAP will have the cost decrease in Eq. Type-3 and will have new costs in other Eq. Types; when other eCall PSAP which is not integrated to the 112 PSAP will have new costs between Eq. Type-1 and Eq. Type-8.
- If the Manual eCall PSAP and Auto eCall PSAP are integrated to the 112 PSAP, Integrated PSAP will have the cost decrease in Eq. Type-3 and will have new costs in other Eq. Types.
- If eCall PSAP(s) are integrated to the Rescue services, its analysis will be detailed in Part 4.3.6.

4.3 Ecall System Infrastructure-2: Rescue Service Stations & Vehicles

Rescue services which are the responsible teams for emergency cases are police, ambulance and fire services. Emergency Call System structures with respect to receiving eCall have been defined in Part 3.2 "The whole generic eCall Structure After eCall equipped vehicle regulation".

The environment of the rescue service responsible person is like in Figure 4.10 and its explanation. In addition to them, it has a dispatch unit which includes the computer-aided dispatch (CAD) system including its management software and workstations. The computer monitors and multiple system equipment can change station to station via its requirements.

According to next generation possible architectures, capacity of workstations can be filled or not. But, telephony and ancillary equipment and dispatch systems are always in usage. On the other hand, network systems may be set up to the rescue stations. Next, rescue services normally have cad system structures such as workstations, networks, message services and dispatch systems for all other public events. Cases in this section are described for emergency service provision of the ecall equipped-vehicles. EROs need to have additional workstations and network-links for eCall equipped vehicle emergency cases if they are giving responses to the emergency callings and making dispatches to the emergency service vehicles.

4.3.1 Emergency Rescue Services' Dispatchers Education Levels

Rescue Service dispatchers can be grouped into three parts via being a trained person as Table 4.14.

Table 4.14 Types of Rescue Service Persons

Rescue Person Type	Definition
Highly Trained	Giving responses to the emergency callings and making the dispatches to all rescue services. (1 Person can take emergency call, define the accident and making the dispatches to all rescue services such as Police, Ambulance, Fire)
Middle-Trained	Make dispatches to all rescue services and sometimes support PSAPs. (No Call-Response, Dispatch can be made to Police Vehicle, Ambulance Vehicle and Fire Vehicle by one person)
Low-Trained	Make dispatches to only its unit. (No Call-Response and; If the rescue person is Police → Dispatch to only Police Vehicle. Other services need their related responsible dispatchers)

4.3.2 Emergency Rescue Service Dispatchers Education Levels in EENA Architectures

The European Emergency Number Association Current Architectures are defined with respect to the emergency rescue service dispatchers :

- In EENA, Model-1 (current statuses of Case Study-4 and Case Study-5 in Chapter-7); one of the rescue service stations includes the 112 PSAP because of the fact that there is no different 112 PSAP service station. 112 PSAP is set up in one of emergency rescue service station and PSAP calls are managed by this emergency rescue service persons. The rescue service person in the rescue service which has 112 PSAP are highly trained when the service persons of the other two rescue service stations are low trained or middle trained.

- In EENA, Model-2 (current status of Case Study-3 in Chapter-7); the emergency service persons are middle trained who makes the dispatch process to the emergency service vehicles.
- In EENA, Model-3; the emergency service persons are middle trained and have the same properties as EENA. Model-2. Additionally, the emergency service persons are supporting the PSAP call takers in some cases and the classified calls in 112 PSAP are forwarded to the rescue service station with parallel dispatch.
- In EENA, Model-4; (current statuses of Case Study-2 in Chapter-7); the emergency service persons are middle trained. In some cases, PSAPs can support the rescue service dispatchers.
- In EENA, Model-5; (current statuses of Case Study-1 in Chapter-7); there is no rescue service units for the dispatch processes. The PSAP call takers are highly trained; so they are giving responses to the emergency callings and they are making dispatches to the rescue service vehicles.
- In EENA, Model-6; rescue service persons are the same as EENA, Model-2 or EENA Model-3 which has an interconnected PSAP structure.

4.3.3 Rescue Service Dispatchers Received Data About the Accidents

The dispatch data to emergency rescue service vehicles by emergency services are the same data of PSAP Call takers data which is explained in Part 4.2.3.

4.3.4 Emergency Services İnfrastructure Materials via Architecture Variants

The infrastructure details of emergency services also include the parts in Table 4.3 when the content of these equipment types are changing in these services and its architectural differences are explained in Part 4.3.5 below.

4.3.5 Details of PSAP İnfrastructures in EENA Current Architectures

The infrastructural difference comes from the rescue service usages in the architectures. There are the different cases for the emergency service infrastructures as below:

- If the emergency service station is used as a different station from PSAPs and there is no parallel dispatch to these services by PSAPs; it does not need any additional infrastructural equipment. For instance, EENA,Model-2 has the 112 PSAP and rescue service stations differently; so its emergency service stations do not include any extra equipment and it has all parts of Table 4.13.
- If one of the rescue services is used as 112 PSAP, this emergency service will have the extra infrastructural equipment and it will have more number of persons. For instance, Model-1 has a 112 PSAP in one of the rescue service stations; so its rescue service including 112 PSAP which has extra PSAP equipment. The other two rescue services do not include any extra equipment.
- If the emergency service station is the same (no PSAP integration) but it giving responses to the PSAPs with its parallel dispatch to these rescue services; it needs any additional infrastructural requirements. For instance, EENA,Model-3 has the 112 PSAP & rescue service stations differently and it has a parallel dispatch structure from 112 PSAP to rescue service stations; so its Eq. Type-1, Eq. Type-3 and Eq.Type-5 of Table 4.13 will be more expensive than EENA, Model-2 structure.
- If the emergency service stations is used in the same control room/building with 112 PSAP; infrastructural requirements will have differences. For instance, EENA, Model-4 has control room/building structure. It’s Eq. Type-3, Eq. Type-5 and Eq. Type-6 of Table 4.13 are cheaper due to being in the same building with 112 PSAP.

4.3.6 Details of Rescue Service İnfrastructures after eCall equipped Vehicle Regulations in 2018

Explained differences in EENA Architectures via Rescue Service Infrastructures will be updated after eCall equipped vehicle regulations. After the regulations, there will be two additional units to the eCall systems as Manual eCall PSAP and Auto eCall PSAP which has been explained in Part 3.2 and its details will be expanded in Part 5.2. These new PSAPs cause to update or modify the current EENA, Architectures. Their Rescue Service Infrastructure details in Part 4.3.5 and in Table 4.13 is changing the items below:

- If the Manual eCall PSAP or Auto eCall PSAP is integrated to one of the rescue services; or it is integrated to control room/building which includes PSAP and rescue services, Integrated Unit including Rescue Service(s) will have the cost decrease in Eq. Type-3 of Table 4.13 and will have new costs in other Eq. Types; when other eCall PSAP which is not integrated to the emergency service(s) will have new costs between Eq. Type-1 and Eq. Type-8.
- If the Manual eCall PSAP and Auto eCall PSAP are integrated to one of the rescue services; or it is integrated to control room/building which includes PSAP and rescue services, Integrated unit will have the cost decrease in Eq. Type-3 of Table 4.13 and will have new costs in other Eq. Types.

4.4 Ecall System Infrastructure-3: Cellular Towers / Communication Networks / CTN

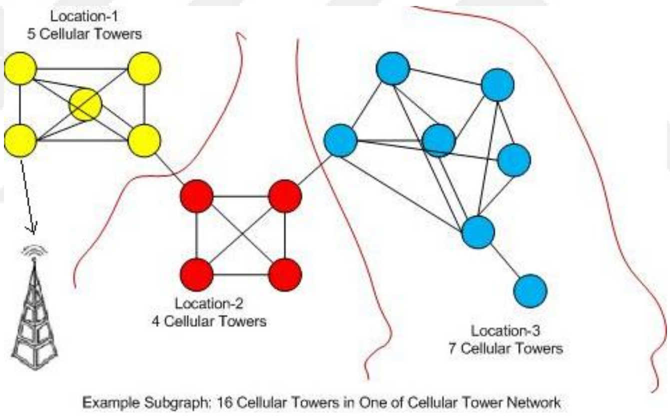

Figure 4.18 Cellular Tower Network (CTN)

Figure 4.18 defines the example of 16-tower sub graph in one of cellular tower network which is segmented into 3 locations and the exist-clusters of nodes are used in ECall Records. When the accident occurs, the emergency call is forwarded to a cellular tower. Each emergency call is recorded in more than one tower with the strongest signal. This data has the duration nearly 30 seconds [148]. Each node in Figure 4.18 is a unique cellular tower enables the data to be represented as cellular tower network. If two towers take the same call, it cannot be a problem due to having an edge between two nodes. Moreover, the capacity of each node (tower) is checked with the total amount of call duration and call events. Cellular tower network has the call-log period included in each of events. Node capacity is also called as node strength which is obviously in usage for the towers. Next, node strength is also associated with the location of accident-callers where the drivers spent their times in vehicle when the accident occurs. In the meantime, cellular tower communication network needs to be fitted with the regulation-ETSI TS-TR126969 [165] which are associated with the data characterization in the emergency calls.

CHAPTER 5

ECALL SYSTEM ARCHITECTURES

5.1 EENA Current Architectures

In the current status without eCall-equipped vehicles, there exist six main emergency system-architectures according to EU-country infrastructures. These 6-models are defined as below [143]:

- Model-1: Emergency Calls EROs handling (Austria, France, Germany, Italy, Norway)
- Model-2: Filtering stage-1 PSAP and resource dispatching stage-2 PSAP (UK, Ireland, Netherland)
- Model-3: Data Gathering by stage1 and resource dispatching by stage2 (Romania)
- Model-4: Data Gathering by stage PSAP1 and resource dispatching by stage PSAP2 in an integrated control room (Belgium, Turkey, Madrid, Ostrava)
- Model-5: ERO Independent PSAP (Finland)
- Model-6: Interconnected PSAP (Sweden, Czech Republic, Bulgaria)

Figure 5.1 shows the scenarios of these architecture models which are used in the EU countries at the current statuses.

Unit-numbers until unit-11 and units between 14 and 16 in the figures are defined in Figure 3.1 and Figure 3.2. In addition to these units, in Figure 5.1; unit-12 describes the interconnected PSAP type (12). Interconnected PSAP explains the PSAPs which are connected to each other in the same region and any of them can response the emergency callings of all PSAPs in the same network. Unit-13 is only one rescue service unit (13) for dispatch process which can be a police station, or ambulance station, or fire station, or a combined unit which is working for all of them to make dispatch. Moreover, Unit-17 is the control room/building structure which can include PSAPs and rescue services in the same destination.

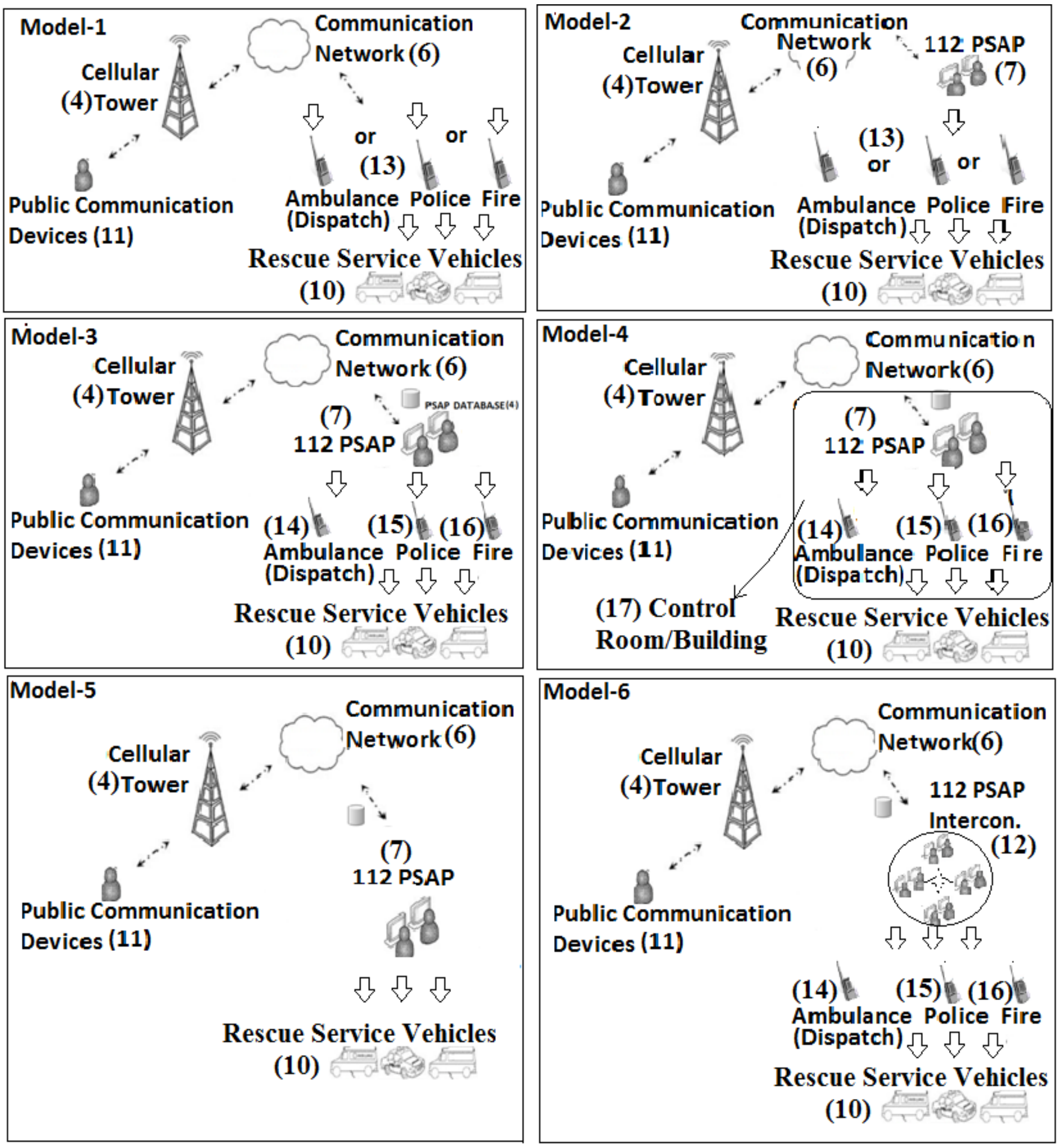

Figure 5.1 EENA Current ECall Architectures [143]

Model-1 in Figure 5.1 is using one of the Rescue services (13) as PSAP and it informs the other-rescue services. Model-2 has a PSAP service (7) and it informs the other related-rescue service(s) (13) about the issue. Next, Civilian call-takers in 112 PSAPs (7) define the calls when EROs (14, 15 and 16) make the dispatches in Model-3. Moreover, Civilian call-takers (7) are working with EROs (14, 15 and 16) in integrated control room/building (17) in Model-4 where the call takers receive the calls. In this model, EROs make the dispatches. Nevertheless, there can be ERO-Independent PSAP structures where the call-takers who are highly-trained (7) make also the dispatches. This is the case of Model-5. In some countries, PSAPs in the same regions can be interconnected (12) and there is no problem if any PSAPs do not have a call-taker in anytime because the other PSAPs can response it due to being interconnected. This type is classified as Model-6.

On the other hand, there exists one more Model which has the architecture includes the control room of PSAP service and one ERO. This architecture is not mentioned in the EENA-Architectures because no country uses this structure at the current status. It can be called as Model-7.

According to European Emergency Number Association (EENA), Finland (case study-1 in Chapter-7) has the emergency service structure as Model-5 in Figure 5.1. In the current status, Highly-trained Civilian Call-Takers (7 in Model-5) are receiving calls and also making dispatches to the related rescue services. There is no any other responsible rescue person for the dispatch process. Next, Turkey (case study-2 in Chapter 7; Model-4 of Figure 5.1) has the control room/building (17) structure where the response to the emergency calls by 112 PSAPs and dispatches to the rescue team vehicles (10) by Rescue Services (14 and/or 15 and/or 16) are made. Moreover, United Kingdom (case study-3 in Chapter 7, Model-2 of Figure 5.1) uses the 112 PSAPs and the call takers in 112 PSAPs are taking only emergency calls and forward it to the related rescue service(s) (14 and/or 15 and/or 16). Related rescue service(s) make the dispatches of emergency cases to the rescue team vehicles (10). The other two case studies in Chapter-7 which are Italy (case study-4) study and Germany (case study-5) study are the structure of EENA, Model-1. They are using one rescue services as PSAPs and the other rescue services are informed if the emergency call is related to them. The rescue service which is used as PSAP is Police Station in Italy and it is Fire Station in

Germany. Rescue services make the dispatch to the related rescue team vehicles in Model-1 of Figure 5.1.

5.2 Future Developments

When the EU-2015/758 regulation is applied in EU Countries in 2018 [2], emergency call architectures are updated or modified via emergency calling structure in the systems in Figure 5.1. Architectures can have different applications due to the reasons listed below:

- PSAPs can be varied as 112 PSAPs, Manuel ECall PSAPs and Automatic ECall PSAPs. (System can have: 112 PSAP + Manuel ECall PSAP, or 112 PSAP +Automatic ECall PSAP, or All of them, or other external cases.)

- PSAPs via call & dispatch processes can be used differently.

- Rescue Services can be informed differently. (Only related Rescue Service Informed by PSAP, or All Rescues informed by PSAP, or One Rescue can be used as PSAP and it informs other rescue services, or PSAP informs 1 Rescue and this rescue informs other rescues etc..)

Next generation eCall cases are analyzed with respect to eCall receivings. New system receiving-types are listed below [143]:

- Type-1: 112 PSAP Receiving's (Expanded-Current Statuses)
- Type-2: 112 PSAP and Manual/Automatic ECall PSAP Receiving's
- Type-3: All PSAPs (112 PSAP, Manual eCall PSAP and Auto Ecall PSAP) Receiving's

These receiving types can be organized as a centralized organization, de-centralized organization or combined organization. Centralised organization means all eCalls are routed to a central PSAP when De-centralized organization reaches the local PSAP for the eCall callings. On the other hand, the combined organization defines the cascade structure of centralized and de-centralized organization. When some areas in the country is de-centralized, some others are centralized in the same country and vice versa [119].

Receiving types can be varied due to handlings. Handlings can be direct handling, indirect handling, and mixed handling. Direct handling takes all eCall recieving at the same PSAP when in-direct handling receives the eCall types from different PSAPs. Mixed handling includes both direct and indirect structures on the same network.

Taking everything into consideration, emergency Call recieving have differences as below:

- Its applicational differences
- Its receiving types
- Its organization types
- Its handling types

These differences will cause to have a multitude of architecture variants after eCall equipped vehicle regulations. These variant details are summarized via functionality, technical aspects and flowcharts for EENA models in Part 5.3.

5.3 Architectures: Up to Date & After Ecall Equipped Vehicle Regulations

The current architectures of European Emergency Number Association (EENA) are summarized in Part 5.1. The combination of the next generation updates, modifications in Part 5.2 and current statuses in Part 5.1 are defined separately. The combination of Part 5.1 and Part 5.2 are analyzed in this section with respect to three topics which are summarized below:

- Functional Descriptions
- Technical Descriptions
- RDVs; Response-Dispatch Variants

Functional Descriptions explains the current statuses and future statuses in the scenarios when Technical Descriptions will define the flowcharts of the processes in the current and future statuses. Finally, Response-dispatch variants are described with respect to architectural differences in the current statuses and next-generation statuses.

5.3.1 EENA Model-1 Architecture Variants After ECall Equipped Vehicle Regulations

According to European Emergency Number Association (EENA) **[135]**, the current and next generation emergency call system of EENA, Model-1 and its response-dispatch variants are analyzed in this Part. Section-1 will be the functional descriptions, then section-2 gives the technical descriptions, finally, response-dispatch variants (RDV-1, RDV-2 and RDV-3) are analyzed. At the end, the EENA,Model-1 next-generation variant possibilities are emphasized. The case study details of EENA, Model-1 which is applied in Germany, Italy will be explained in Case Study-4 and Case Study-5 of Chapter-7.

5.3.1.1 Functional Description of EENA Model-1 Architectures

- Functional Description-1: Current Emergency Call System of EENA, Model-1 via Public Communication

According to European Emergency Number Association (EENA) [135], the current emergency call system of EENA, Model-1 can be described as it is shown in Figure 5.2. In Figure 5.2, Unit-20 is the rescue service (15) which includes 112 PSAP (7). The rescue service which is used as 112 PSAP is the police station and it is the example of Italy infrastructure. Its example of Germany Infrastructure includes Fire station (16) usage as 112 PSAP (7).

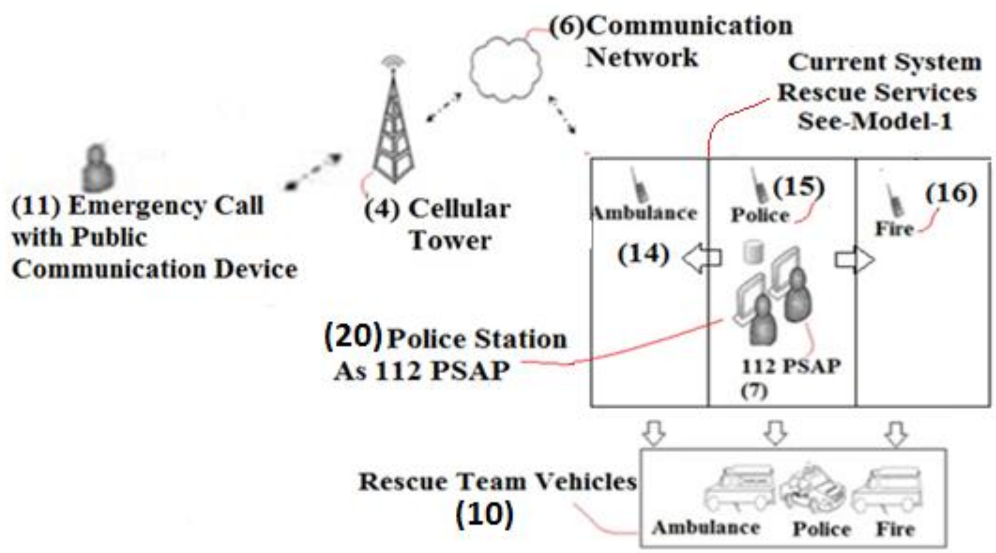

Figure 5.2 EENA, Model-1 General Scenario of Public Communication [143]

Figure 5.2 is the Model-1 in Figure 5.1. Its structural difference with the generic case in Figure 3.2 is the relation of Rescue services. One of rescue service in this structure includes the 112 PSAP. The other parts of the structure are the same as the general scenario. There exists most appropriate 112 PSAP (7) in one of rescue service. The rescue service (15) which includes the 112 PSAP (7) is the police station in the example of Figure 5.2 at the current status. This structure is the example of Italy Infrastructure. In Germany Infrastructure, the 112 PSAP (7) at the current status is in Fire Stations

(16). In this structure, 112 PSAP responsible persons have the ability to make dispatches to the station where it is set up. It also informs the other rescue services if the emergency calling is related to them. In Figure 5.2, police station (15) is the 112 PSAP (7) and it informs the other rescue services (14 and 16). This is the functional description of the current system. To understand the emergency call current status for vehicle application, next part will describe the same architecture status via vehicle application.

- Functional Description-2: Current Emergency Call System of EENA, Model-1 via Vehicle Application

Few volume eCall equipped vehicles are used at the current status without any regulations in the countries. Their usage is based on test evaluations of product developments, research development or accessories of luxury cars. The emergency call situation in this type of application at the current status in Model-1 of EENA Architecture will be explained in Figure 5.3.

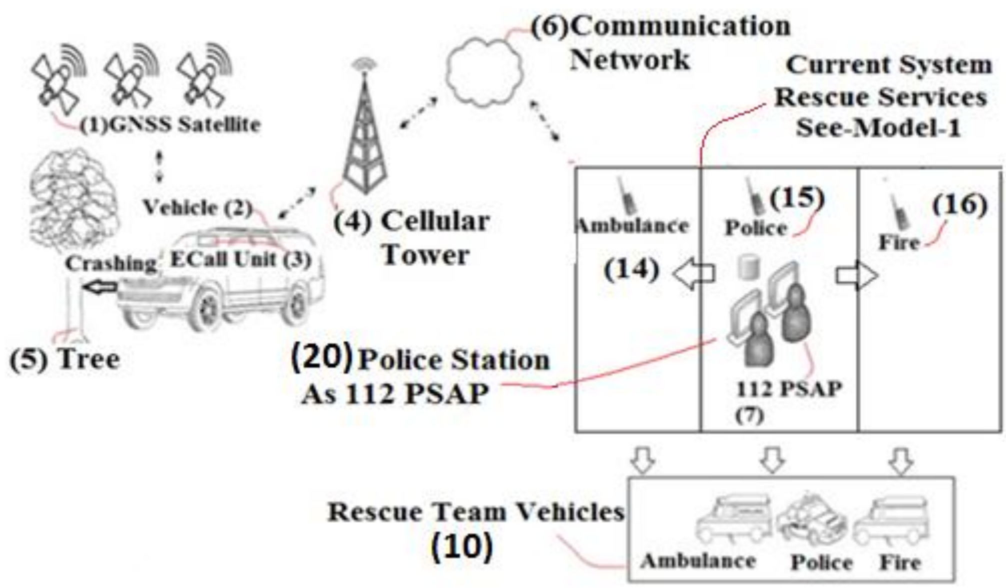

Figure 5.3 EENA, Model-1 General Scenario of Vehicle eCall Process [143]

Figure 5.3 defines the accident case to understand how the emergency cases are processed via vehicle application at the current status in EENA Model-1. The difference between being vehicle application in Figure 5.3 and being a public communicational application in Figure 5.2 is the communication process (6) of receiving signals. The receiving structure via vehicle application in EENA Model-1 at the current status can be more than one type: (i) firstly the signals go to vehicle OEM database, and then it is forwarded to the 112 PSAP (ii) the second alternative can be directly forwarded to the 112 PSAP. The other procedures of Figure 5.3 are the same about vehicle application with Figure 3.2 and the same about emergency service structure with Figure 5.2.

These functional definitions enable to understand the current EENA architecture, Model-1; which is applied in Italy, Germany (case study-4 and Case Study-5 in Chapter-7) at the current status. When the eCall equipped vehicle regulations are an obligation in 2018, the system will have the changes. To understand the new architecture generic status and possible changes, a general overview will be defined in the next section with Figure 5.4 and its explanation.

- Functional Description-3: Next Generation Emergency Call System of EENA, Model-1 After eCall Equipped Vehicle Regulations

When EU-2015/758 [2] is started to be applied in the European Countries, the current emergency call systems in EENA, Model-1 will be updated or modified via giving responses to the emergency calls and making dispatches by Emergency Response Organizations (EROs). Its content is associated with new types of PSAPs and eCall receivings. Figure 5.4 shows the next generation eCall system with generic EENA architecture of Model-1. It does not depend on any specific infrastructure of the country; this is to say, it is the general version. Its country-specific status will be detailed in Chapter-7 in Case Study-4 and Case study-5 for Italy and Germany.

The units in Figure 5.4 are explained in Figure 3.1, Figure 3.2, Figure 5.1, Figure 5.2 and in Figure 5.3 except for unit-8 and unit-9. When unit-8 defines the Manual eCall PSAP (8) which responses the accident of vehicles including manual eCall device, unit-9 explains the Auto eCall PSAP (9) which responses the accident of the vehicles including automatic eCall device.

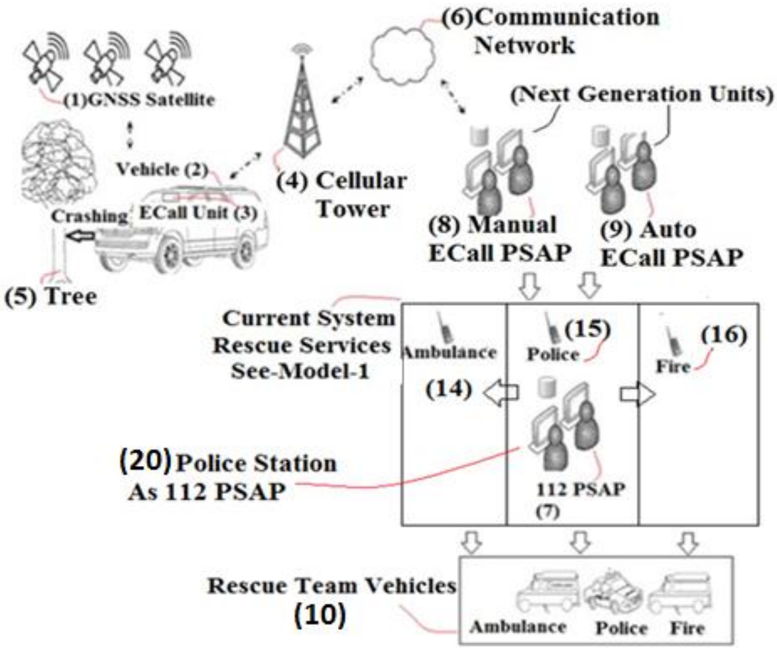

Figure 5.4 Next Generation EENA, Model-1 General Scenario of Vehicle eCall Process

In Figure 5.4, the same scenario with Figure 5.3 about the activation of vehicle eCall unit is used. The process flow until the communication network process (1 to 6) includes the same procedures not only in Figure 5.3 but also in Figure 5.4. After the accidents data is forwarded by the communication network to the public safety answering points, the process will be varied. The Communication network can transfer the emergency call data to the three types of PSAPs (7 and/or 8 and/or 9) in Figure 5.4. These are; (i) 112 PSAP (7), (ii) manual emergency call PSAP (8), (iii) automatic emergency call PSAP (9). According to country infrastructure and system architecture, the accident data can be sent only one of them, two of three answering points or all of them. The Case Studies in Chapter-7 will explain the details of the future steps via country infrastructures. After the accident data is evaluated by PSAP service(s) (7 and/or 8 and/or 9), it will be sent to the related rescue station(s) (14 and/or 15 and/or 16). The data are stored in their databases. Next, the dispatch process is made by Rescue Stations. Finally, the rescue service vehicles (10) enable the help to the accident places.

5.3.1.2 Technical Descriptions of EENA Model-1 Architectures

- <u>Technical Description-1: Current ECall System of EENA Model-1</u>

This part explains the data processes of current emergency call system in EENA Model-1 for any public issue with filtering calls in 112 PSAP which is set up in the one of rescue service station and resource dispatching by related rescue service(s). It is the usage of Germany Infrastructure (Case Study-5 in Chapter-7) and Italy infrastructure (Case Study-4 in Chapter-7). It schemes in Figure 5.5.

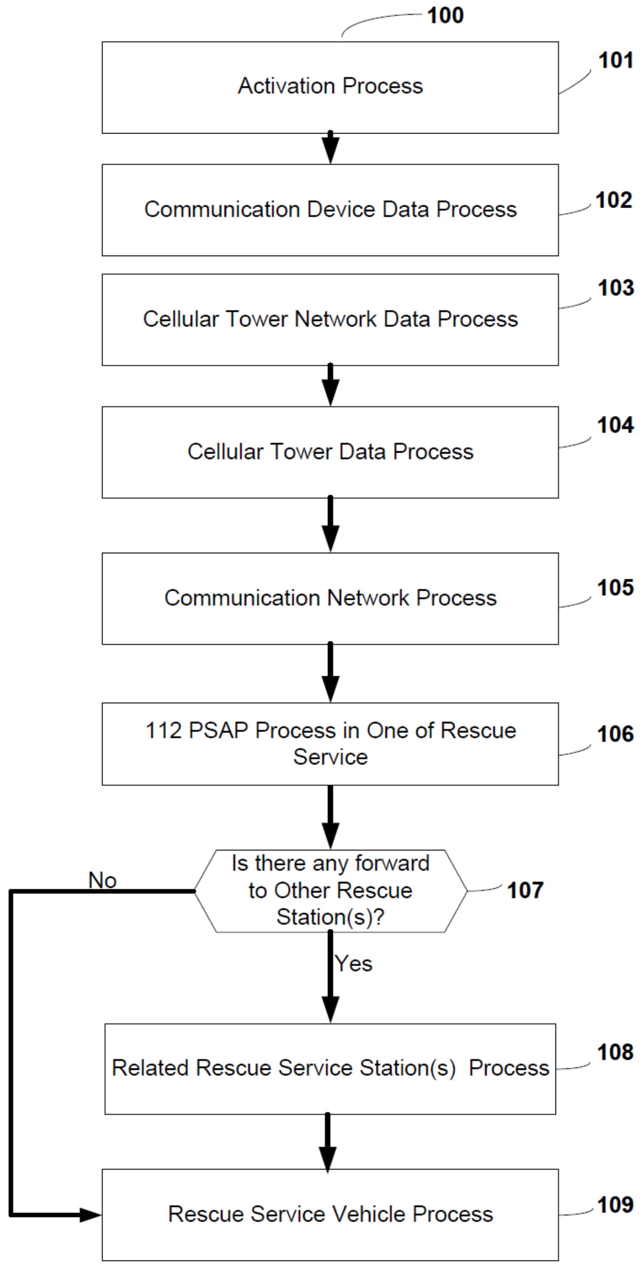

Figure 5.5 Current eCall System Flowchart of EENA,Model-1

Figure 5.5 explains the flow (100) of current status in emergency cases with this type of architecture. When there is an accident, activation process (101) is provided by communication device. When its user enables the required inputs into the communication device, its processor is in progress to call the required help. When the device processor processes the data, supply voltage is provided by communication device battery. The input signals are transmitted to the data entities which are fitting the requirements of sending data format. After this activation and device processes (102), signals are sent to cellular tower network. Cellular tower network (CTN) is a network of cellular tower subgroups and enables the newcomer data to be forwarded to the available cellular tower (103). It chooses the correct cellular tower with the parameters: (i) cellular tower own-capacity, (ii) signal power, (iii) cellular tower usages (iv) edge technology in subgroups. When the signal comes to the CTN, its power is measured. The cellular tower usages and cellular tower own capacities are known in cellular tower network database. Next, the emergency case signal is sent to the available cellular towers; and then the edge technology enables the filtration of the signals. Edge technology is a framework between cellular towers. If one of signals goes more than one tower, it enables to forward the emergency case signals to one direction in one cellular tower. Moreover, cellular tower takes the signals (104), stores it into its own database and forward them to the related 112 PSAP. Cellular tower processes the data entities such as 2G, 3G, 4G, 5G or available future communication data type. They can be directly received as appropriate data type or it can be transmitted to the appropriate data in the cellular tower. This process can be made by hand-made code writings which means the specific codes for cellular towers or enabled by standard packages for cellular towers which are embedded to the cellular tower subgroups generally. After this flow, the emergency case data are forwarded to the communication network. Communication network transfers the data to the possible 112 PSAP service (105). 112 PSAPs are set in the zones in the country and the numbers of 112 PSAPs in these zones are known. CTN chooses the available 112 PSAP at the related zone and 112 PSAP defines the emergency case, processes its data, stores them in its own database and forward them to the related rescue service station(s) if the other rescue stations are related with the emergency case. 112 PSAP is set into the one of rescue service station when the other rescue stations are also at the different stations. 112 PSAP services in this type are not only responding the emergency cases to ask which rescue service(s) are needed but also making dispatches to the rescue team vehicles where it is set up (106). There can be two options of processes after the emergency calling is at the 112 PSAP which is inside of one of the rescue station (police station or ambulance station or fire station) :

- The other rescue service stations which does not include 112 PSAP are informed about emergency callings if they are related with it (107-108). These Rescue service(s) is/are only making dispatches to the related rescue team vehicle(s). 112 PSAPs are reaching them, they do not give responses to the emergency callings. Then, related rescue service-station(s) are in progress. They store the data and make the dispatches. Finally, rescue service vehicles take the required emergency case data, process them and reach to the emergency place (109).
- If the emergency call is not related to other rescue service stations, it is directly dispatched to its own rescue team vehicle (107-109).

- Technical Description-2: Next Generation Emergency Call System of EENA Model-1

The technical description of the flowchart for current emergency call architecture of EENA Model-1 is explained in the last section above. In this part, next generation emergency call system structure will be defined for EENA Model-1. It will be used in Germany Infrastructure (Case Study-5 in Chapter-7) and Italy infrastructure (Case Study-4 in Chapter-7) after eCall equipped vehicle regulations. It schemes in Figure 5.4 and its flowchart (200) is defined in Figure 5.6.

In Figure 5.6, the activation process (201) is enabled when the accident occurs. The data sending from vehicle to cellular tower network is different from the next generation system. It is different from the current status of Figure 5.5. Vehicle data process depends on having an automatic eCall device (204-203) or having a manual eCall device (204-202). Automatic eCall device is triggered automatically when manual eCall device is triggered by external input. In addition, automatic eCall device works without any external input and it is activated when there is an accident. On the other hand, manual eCall device in the vehicle works with the external input which is enabled by the buttons on the emergency call device and activated by passengers or driver. Taking eCall device processes (205) in Figure 5.6 into consideration, data is gathered, transmitted and complied; then, it is sent to CTN. The flow between CTN (206) and communication network (208) is the same with the flowchart in Figure 5.5 (like between 103 and 105).

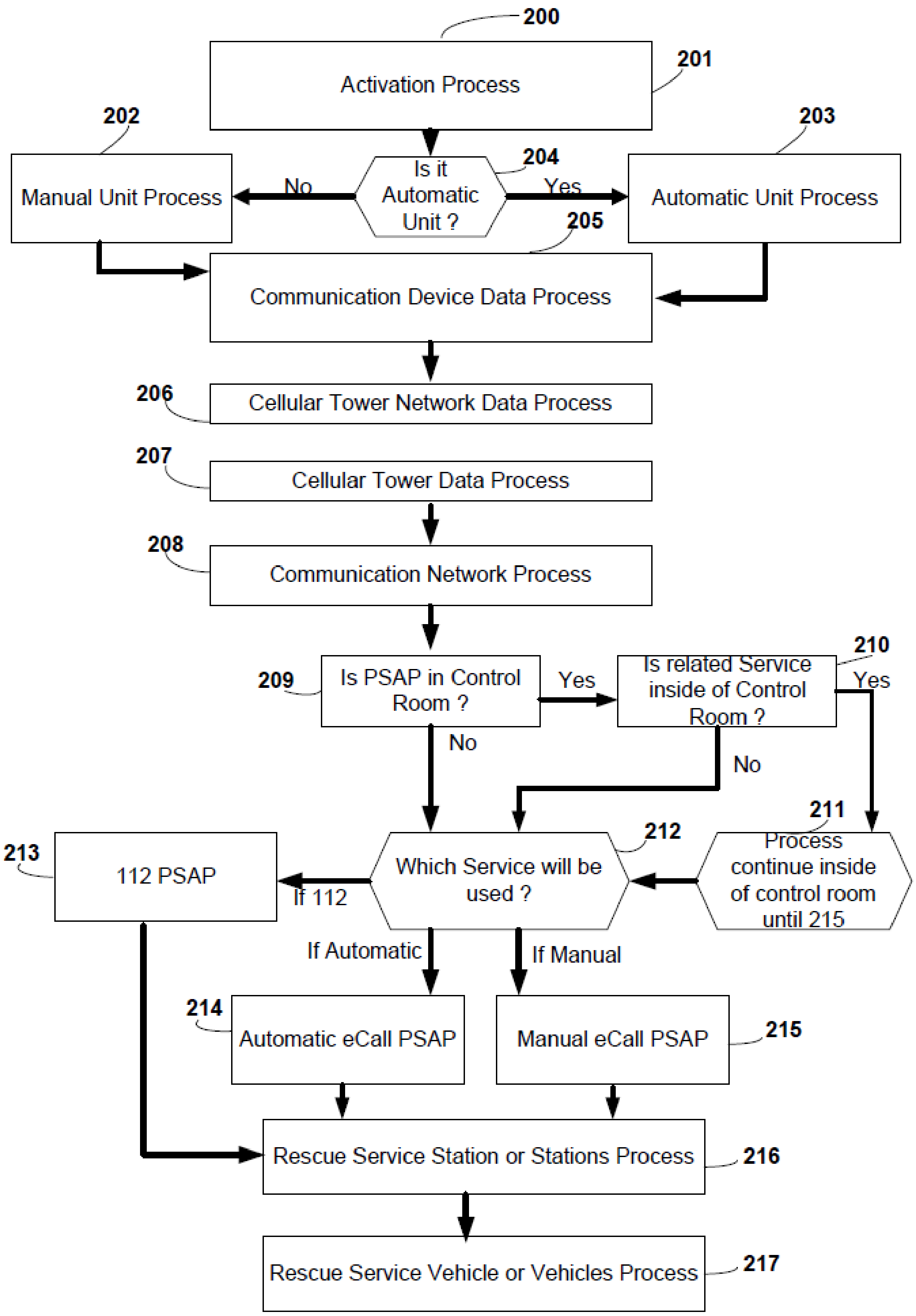

Figure 5.6 Next-Generation eCall System Flowchart of EENA,Model-1

After the output is ready in a communication network(208) in Figure 5.6, PSAP process (209) starts. First of all, it is decided whether the PSAPs have control room structure or not (209). If the services are in control room/building, its infrastructure and flows continue at the same room/ building; so the process is explained with 210 and 211. If the service is outside of control room, the process is connected to 212 directly. The flow continues with the same logic after 212. 210 and 211 emphasize the infrastructure differences. When the service is chosen whether being 112 PSAP, manual eCall PSAP or Automatic eCall PSAP; the flow continues with 213 and/or 214 and/or 215. In all PSAP services, data is stored in their own databases, is processed in their stations and is forwarded to the rescue station(s). The data is in progress in the rescue stations (216), and then the rescue services make the dispatches to the rescue service vehicles. Finally help is provided by rescue service vehicles (217).

5.3.1.3 Response-Dispatch Variants of EENA Model-1 Architectures

Thanks to new eCall receiving types after the regulations; new structure of EENA-Model 1 for call-responses and making-dispatches are summarized with their variants as below:

- RDV-1: Both Response-Dispatch Variant within Rescue Station Applications
- RDV-2: Only Response-Variants
- RDV-3: Only Dispatch Variants

In these structures, Both Response-Dispatch variant (RDV-1) means the giving responses to the emergency callings and making dispatches to the rescue team vehicles can be processed by the same PSAP or Rescue services. On the other hand, only Response variants (RDV-2) are giving responses to the emergency callings and they do not make dispatches when only Dispatch Variants (RDV-3) makes dispatches to the related rescue services or rescue team vehicles.

In the application (see case-studies in Chapter-7), RDV-1 variants can be applied directly or RDV-2 and RDV-3 correlations can be set up.On the other hand, the other RDV's (RDV-4 or RDV-5---explained in the next sections) can be applied if the country infrastructures are re-organized.

- RDV-1: Both Response-Dispatch Variant Applications*:*

➢ ECall Response-Dispatch Variant-1: There can be 112 PSAP and Manuel eCall PSAP in different buildings when there is no automatic eCall PSAP.112 PSAP is in one of rescue service station.112 PSAP responses other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. That means the 112 PSAP is in one of rescue service station. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device.

-In this type, another type of the variant can exist. 112 PSAP may response not only other public issues but also the accident issues of vehicles which have automatic eCall device and making dispatches to the rescue team vehicles about automatic eCall equipped vehicle accidents & other public issues of emergency callings. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. 112 PSAP and automatic eCall PSAP is in one of rescue service station when Manual eCall PSAP is at a different station.

-In this type, another type of the variant can exist. In this variant, 112 PSAP may response only other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. That means the 112 PSAP is in one of rescue service station. In addition, the automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. Next, Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. 112 PSAP and Automatic eCall PSAP can be in the same building when Manual eCall PSAP can be in a different building. That means 112 PSAP and Automatic eCall PSAP is in one of Rescue Service Station.

- ECall Response-Dispatch Variant-2: There can be 112 PSAP and Automatic eCall PSAP in the different buildings when there is no manual eCall PSAP.112 PSAP is in one of rescue service station.112 PSAP responses other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. That means the 112 PSAP is in one of rescue service station. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device.

  - In this type, another type of the variant can exist. 112 PSAP can response not only other public issues but also the accident issues of vehicles which have manual eCall device and making dispatches to the rescue team vehicles. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. The expanded 112 PSAP (112 PSAP covering Manual eCall PSAP issues) is in one of the rescue service station when Automatic eCall PSAP is at a different station.

  - In this type, there exist another variant. 112 PSAP can response only other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. That means the 112 PSAP is in one of rescue service station. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. 112 PSAP and Manual eCall PSAP can be in the same building when Automatic eCall PSAP can be in a different building. In addition to them, 112 PSAP and Manual eCall PSAP are in one of rescue service station.

- ECall Response-Dispatch Variant-3: There can be all types of PSAPs as 112 PSAP, manual eCall PSAP, automatic eCall PSAP.112 PSAP can be in one of rescue service station and All PSAPs can be in the different buildings.112 PSAP responses other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. That means the 112 PSAP is in one of rescue service station. Automatic eCall PSAP responses the accident of vehicles which have automatic eCall device. In addition, manual eCall PSAP responses the accident of vehicles which have manual eCall device.

  - In this type, another type of variant can exist. 112 PSAP is in one of rescue service station. 112 PSAP can response other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. The other PSAP can be the combination of Manual eCall PSAP and Automatic eCall PSAP. 112 PSAP and eCall PSAP is in the different buildings. The combined eCall PSAP responses the accident issues of vehicles which have automatic eCall device or manual eCall device.
- ECall Response-Dispatch Variant-4: There can be 112 PSAP and Manual eCall PSAP in the same building when there is no automatic eCall PSAP. In addition, 112 PSAP and Manual eCall PSAP is in one of the rescue services. 112 PSAP responses other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device in the integrated control room/building model. Manual eCall PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles.

  - In this type, another variant can exist. 112 PSAP can response not only other public issues but also the accident issues of vehicles which have automatic eCall device and making dispatches to the rescue team vehicles. 112 PSAP is in the same integrated room/building with Manual eCall PSAP and one of rescue service station. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device and making dispatches to the rescue service vehicles.

- ECall Response-Dispatch Variant-5: There can be 112 PSAP and Automatic eCall PSAP in the same building when there is no manual eCall PSAP.112 PSAP and Automatic eCall PSAP are in one of the rescue service station. 112 PSAP responses other public issues. 112 PSAP which is in one of rescue service station makes dispatches to only this rescue team vehicles. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device.

  -In this type, another type of the variant can exist. 112 PSAP can response not only other public issues but also the accident issues of vehicles which have manual eCall device and making dispatches to the rescue service team vehicles. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. 112 PSAP and Automatic eCall PSAP inside one of the rescue service station can be the integrated control room/building.
- ECall Response-Dispatch Variant-6: There can be all types of PSAPs such as 112 PSAP, manual eCall PSAP, automatic eCall PSAP. All PSAPs can be in the same building.These PSAPs are also in one of the rescue service station. When 112 PSAP responses the other public issues and making dispatches to the rescue service vehicles, Automatic eCall PSAP responses the accident of vehicles which have automatic eCall device. In addition, manual eCall PSAP responses the accident of vehicles which have manual eCall device. They are all in integrated control room/building which means the same database.

  -In this type, another type of the variant can exist. 112 PSAP can response other public issues and making dispatches to the rescue team vehicles. The other PSAP can be the combination of Manual eCall PSAP and Automatic eCall PSAP in the same building with 112 PSAP. These PSAPs are also in one of the rescue service station. This combined eCall PSAP responses the accident issues of vehicles which have automatic eCall device or manual eCall device.

- RDV-2: Only Response-Variants:

- ECall Response Variant-1: There can be 112 PSAP and Manual eCall PSAP in the different buildings when there is no automatic eCall PSAP. While 112 PSAP responses other public issues, Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device.

  -In this type, another type of the variant can be the 112 PSAP may response not only other public issues but also the accident issues of vehicles which have automatic eCall device. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device.

-In this type, another type of variant can exist. In this variant, 112 PSAP may response only other public issues when the automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. 112 PSAP and Automatic eCall PSAP can be in the same building when Manual eCall PSAP can be in a different building.

- ECall Response Variant-2: There can be 112 PSAP and Automatic eCall PSAP in the different buildings when there is no manual eCall PSAP. When 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device.

  -In this type, another type of the variant can exist. 112 PSAP can response not only other public issues but also the accident issues of vehicles which have manual eCall device. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device.

  -In this type, there exist another variant. When 112 PSAP can response only other public issues, automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. 112 PSAP and Manual eCall PSAP can be in the same building when Automatic eCall PSAP can be in a different building.

- ECall Response Variant-3: There can be all types of PSAPs as 112 PSAP, manual eCall PSAP, automatic eCall PSAP. All PSAPs can be in the different buildings. When 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident of vehicles which have automatic eCall device. In addition, manual eCall PSAP responses the accident of vehicles which have manual eCall device.

  -In this type, another type of variant can exist. 112 PSAP can response other public issues and the other PSAP can be the combination of Manual eCall PSAP and Automatic eCall PSAP. 112 PSAP and eCall PSAP is in the different buildings. The combined eCall PSAP responses the accident issues of vehicles which have automatic eCall device or manual eCall device.

- ECall Response Variant-4: There can be 112 PSAP and Manual eCall PSAP in the same building when there is no automatic eCall PSAP. While 112 PSAP responses other public issues, Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device in the integrated control room/building model.

-In this type, another variant can exist. 112 PSAP can response not only other public issues but also the accident issues of vehicles which have automatic eCall device. 112 PSAP is in the same integrated room/building with Manual eCall PSAP. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device.

- <u>ECall Response Variant-5:</u> There can be 112 PSAP and Automatic eCall PSAP in the same building when there is no manual eCall PSAP. When 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device in the integrated control room/building.

  -In this type, another type of the variant can exist. 112 PSAP can response not only other public issues but also the accident issues of vehicles which have manual eCall device. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device.112 PSAP and Automatic eCall PSAP can be in the same integrated room/building.

- <u>ECall Response Variant-6:</u> There can be all types of PSAPs such as 112 PSAP, manual eCall PSAP, automatic eCall PSAP. All PSAPs can be in the same buildings. When 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident of vehicles which have automatic eCall device. In addition, manual eCall PSAP responses the accident of vehicles which have manual eCall device. They are all in integrated control room/building which means the same database.

  -In this type, another type of the variant can exist. 112 PSAP can response other public issues. The other PSAP can be the combination of Manual eCall PSAP and Automatic eCall PSAP in the same building with 112 PSAP. This combined eCall PSAP responses the accident issues of vehicles which have automatic eCall device or manual eCall device.

  - <u>RDV-3: Only Dispatch-Variants:</u>

  Thanks to one of response types (RDV-2), the accident data can be forwarded to the rescue service(s). The dispatches are made by one of dispatch types below:

- <u>Ecall Dispatch Variant-1:</u> Rescue Services; police, ambulance and fire stations can be in the different stations. All types have different types of dispatch units.

- Ecall Dispatch Variant-2: Rescue Services can have one dispatch unit with highly trained rescue persons at the different building which does not include any PSAP service persons. This type of services can make dispatches to all types of rescue service vehicles such as police vehicles, ambulance vehicles, and fire vehicles.
- Ecall Dispatch Variant-3: Rescue Services can have one dispatch unit with highly trained rescue persons at the same building with PSAP service persons. This type of services in the integrated control room/building can make dispatches to all types of rescue service vehicles such as police vehicles, ambulance vehicles, and fire vehicles.
- Ecall Dispatch Variant-4: Rescue Services can have different dispatch units in the same building with PSAP service persons. This type of services can make dispatches to only their service vehicles such as; police rescue-dispatcher makes the dispatches to police service vehicles, ambulance rescue-dispatcher makes the dispatches to ambulance service vehicles, fire rescue-dispatcher makes the dispatches to fire service vehicles in the integrated control room/building. All rescue service dispatchers and PSAP service persons are in the same room/building.

Taking everything into consideration, there will be 38 variants for all EENA architectures of next-generation system. 12 of 38 architectures will have the availability via infrastructure for EENA, Model-1 which is applied in Germany, Italy. The numbers in gray area in Table 5.1 below shows the possible applicable architecture numbers of 38 variants with respect to the models and eCall receiving types. The gray areas mean the 12 applicable architectures which can be fitted with EENA,Model-1 are produced by these type/model correlations.

Table 5.1 New ECall System Architectures (Author's Calculations)

EENA Ecall Architectures[16] / New ECall Variants	Type-1: Most Appropriate 112 PSAP	Type-2: 112 PSAP + Manuel (or) Auto Ecall PSAP	Type-3: 112 PSAP + Manuel ECall PSAP+ Auto ECall PSAP
Model-1	1	0	0
Model-2	1	1	1
Model-3	1	1	2
Model-4	1	2	5
Model-5	1	7	13
Model-6	1	1	2
Model-7	1	1	2

In case study-4 and case study-5 in Chapter-7, which architectures can be applied as the update or modification of EENA,Model-1 (update of Figure 5.3), “Emergency Calls EROs handling ” will be analyzed. After the detailed analysis in the Chapter-6 “Cost Model Study”, the optimal next generation architecture of current EENA, model-1 applied in Italy, Germany is advised in the Case study-4 and case study-5 of Chapter-7 “Case Studies”.

5.3.2 EENA Model-2 Architecture Variants After ECall Equipped Vehicle Regulations

According to European Emergency Number Association (EENA) [135], the current and next generation emergency call system of EENA, Model-2 and its response-dispatch variants are analyzed in this Part. Section-1 will be the functional descriptions, then section-2 gives the technical descriptions, finally, response-dispatch variants (RDV-2 and RDV-3) are analyzed. At the end, the EENA,Model-2 next-generation variant possibilities are emphasized. The case study details of EENA, Model-2 which is applied in the United Kingdom will be explained in Case Study-3 of Chapter-7.

5.3.2.1 Functional Descriptions of EENA Model-2 Architectures

- <u>Functional Description-1: Current Emergency Call System of EENA, Model-2 via Public Communication:</u>

According to European Emergency Number Association (EENA) [135], the current emergency call system of EENA, Model-2 can be described as it is shown in Figure 5.7. In Figure 5.7, Unit-13 is the related rescue service(s) (13) such as Police Station and/or Ambulance Station and/or Fire Station. The emergency stations will have the different number of units in this article (14, 15 and 16 in Figure 3.1), but unit-13 means the rescue service(s) which are related to an emergency case when it occurs. It also means; if any type of rescue stations is not related to the emergency case, it is not informed.

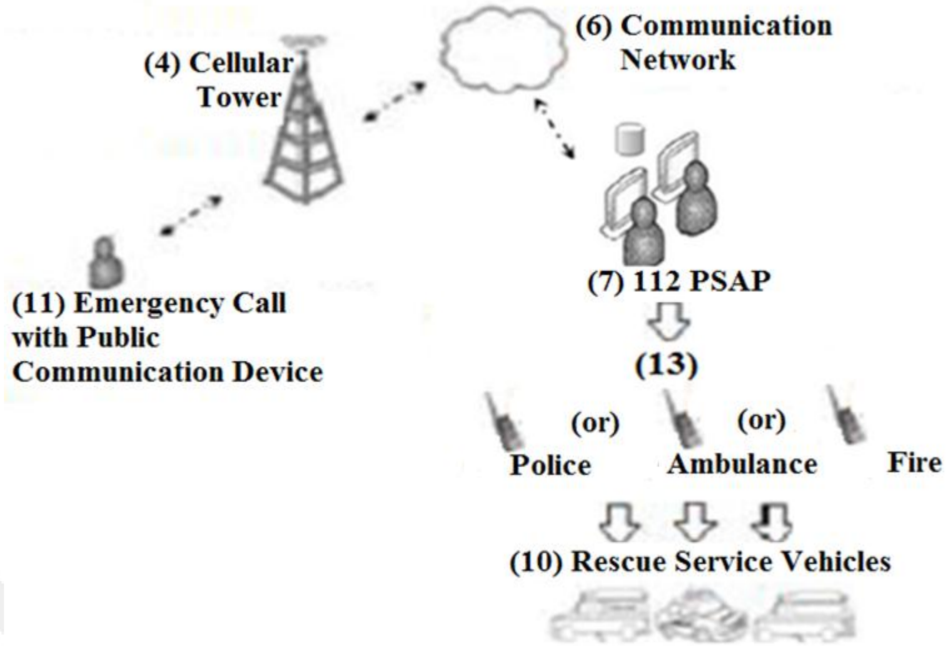

Figure 5.7 EENA, Model-2 General Scenario of Public Communication [143]

Figure 5.7 is the Model-2 in Figure 5.1. Its structural difference with the generic case in Figure 3.1 is the relation of rescue services and PSAPs. The other parts of the structure are the same as the general scenario. There exists most appropriate 112 PSAP (7) at the current status. It takes the signals such as text-message, audio data, or video data; and then processes it. 112 PSAP in this system is only asking which rescue service is required and forward it to the related rescue station(s) (13). In this structure, 112 PSAP responsible persons do not have the ability to make dispatch. They can only give responses to the emergency callings and forward them to the related EROs. This is the functional description of the current system. To understand the emergency call current status for vehicle application, next part will describe the same architecture status via vehicle application.

- <u>Functional Description-2: Current Emergency Call System of EENA, Model-2 via Vehicle Application</u>

There is no regulation obligations and few volume eCall equipped vehicles are used at the current status without any regulations in EENA, Model-2 countries. The emergency call situation via vehicle application at the current architecture of EENA, Model-2 will be explained in Figure 5.8.

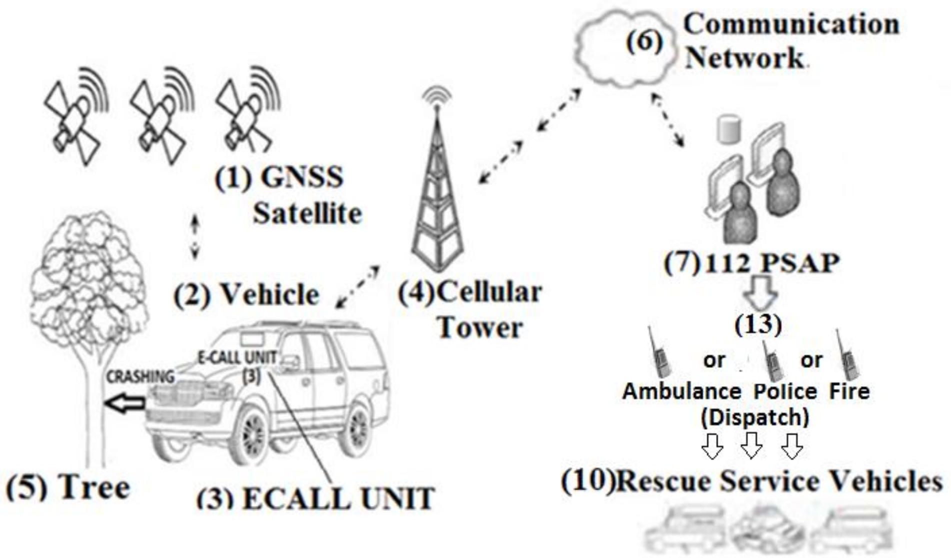

Figure 5.8 EENA, Model-2 General Scenario of Vehicle eCall Process [143]

Figure 5.8 defines the accident case to understand how the emergency cases are processed via vehicle application at the current status in EENA Model-2. The difference between being vehicle application in Figure 5.8 and being public communication in Figure 5.7 is the communication process (6) of receiving signals. The receiving signal structure via vehicle application in EENA Model-2 at the current status is the same with the Functional Description-2 of Part 5.3.1.1. The difference between Figure 5.8 and Figure 5.3 is the PSAP and rescue service(s) structure. When there is no external 112 PSAP in Figure 5.3 that means 112 PSAP is set up in one of the rescue services, 112 PSAP is a different service station in Model-2 applications in Figure 5.8.

These functional definitions enable to understand the current EENA architecture, Model-2; which is applied in United Kingdom (case study-3 in Chapter-7) at the current status. When the eCall equipped vehicle regulations are an obligation in 2018, the system will have the updates and modifications. The general overview will be detailed in the next section with Figure 5.9.

- Functional Description-3: Next Generation Emergency Call System of EENA,Model-2 After eCall Equipped Vehicle Regulations:

When the European Union Regulation EU-2015/758 [2] is started to be applied in the European Countries, current emergency call systems will be updated or modified via taking emergency calls and Emergency Response Organizations (EROs). Its content is associated with PSAP types and eCall receiving types. Figure 5.9 shows the next generation emergency call system with generic EENA architecture of Model-2.

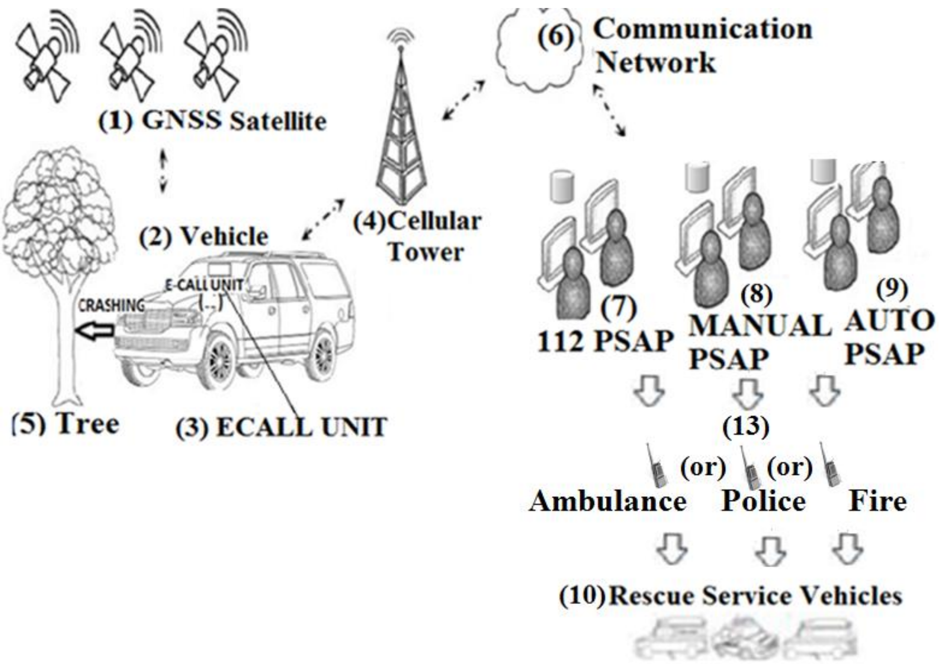

Figure 5.9 Next-Generation EENA, Model-2 General Scenario of Vehicle eCall Process

In Figure 5.9, the same scenario with Figure 5.8 about the activation of vehicle eCall unit is used. The process flow until the communication network process (1 to 6) includes the same procedures not only in Figure 5.8 but also in Figure 5.9. After the accidents data is forwarded by the communication network to the public safety answering points, the process will be varied. The communication network can transfer the emergency call data to the three types of PSAPs (7 and/or 8 and/or 9) in Figure 5.9. These are; (i) 112 PSAP (7), (ii) manual emergency call PSAP (8), (iii) automatic emergency call PSAP (9). After the accident data is evaluated by PSAP service(s) (7 and/or 8 and/or 9), it will be sent to the related rescue station(s) (13; it means 14 and/or 15 and/or 16). The other sides of functional flow is the same with the prosess of Part 5.3.1.1.

5.3.2.2 Technical Descriptions of EENA Model-2 Architectures

- Technical Description-1: Current ECall System of EENA Model-2

This part explains the data processes of current emergency call system for any public issue with filtering calls in Stage-1 PSAP and resources dispatching by Stage-2 PSAP which is in usage in the United Kingdom. It schemes in Figure 5.10.

Figure 5.10 explains the flow (100) of current status in emergency cases with this type of architecture. The process of activation process (101) and communication network (105) are the same with Figure 5.5 in Part 5.3.1.2.

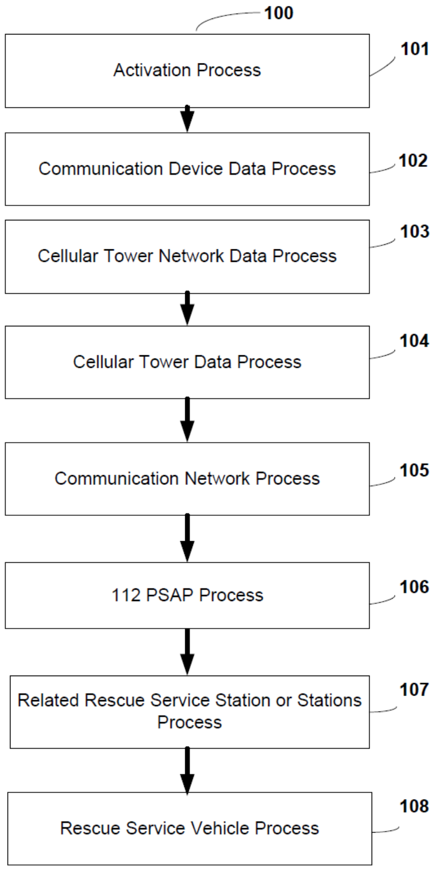

Figure 5.10 Current eCall System Flowchart of EENA,Model-2

In Figure 5.10, CTN chooses the available 112 PSAP at the related zone and 112 PSAP defines the emergency case, processes its data, stores them in its own database and forward them to the related rescue service station(s). 112 PSAPs are placed in different buildings when the rescue stations are also at the different stations. 112 PSAP services of this type are only responding the emergency cases to ask which rescue service(s) are needed. They do not make any other processes such as dispatching, mapping etc. (106). Then, related rescue service-station(s) are in progress. They store the data and make the dispatches (107). Finally, rescue service vehicles take the required emergency case data, process them and reach to the emergency place (108).

- Technical Description-2: Next Generation Emergency Call System of EENA Model-2

The technical description of the flowchart for current emergency call architecture of EENA Model-2 is explained in the last section above. In this part, next generation emergency call system structure will be defined for EENA Model-2. The flowchart (200) is defined in Figure 5.6. Every step of flow are the same. The only difference in EENA,Model-2, it is needed to be emphasized, is the 112 PSAP (213 in Figure 5.6) is a different unit from rescue services as it is shown in Functional Descriptions of EENA, Model-2. That means, 112 PSAP is not integrated part of rescue service station and its flow is needed to be varied via its fitting structure. If the structure change can be applied; maybe, 112 PSAP can be integrated with rescue service stations. Its architecture variants will be studied to understand the optimal next generation status in Chapter-6 'Cost Model Study' and its comparison results are defined in the Chapter-7 Case Study-3 for United Kingdom infrastructure which has the current architecture as EENA,Model-2.

5.3.2.3 Response-Dispatch Variants of EENA Model-2 Architectures

Thanks to new eCall receiving types after the regulations; the new structure of EENA-Model 2 for call-responses and dispatches are summarized with their variants as RDV-2 and RDV-3 correlations. They have been explained in Part 5.3.1.3.

Taking everything into consideration about RDV-2 and RDV-3 via EENA, Model-2, there will be 10 of 38 architectures will have the availability via infrastructure for EENA, Model-2 which is applied in the United Kingdom. Table 5.2 shows the 38 variants with respect to the models and eCall receiving types. The gray areas in Table 5.2 mean the 10 applicable architectures which can be fitted with EENA,Model-2 are produced by these type/model correlations.

Table 5.2 New ECall System Architectures of EENA Model 2(Author's Calculations)

EENA Ecall Architectures[16] / New ECall Variants	Type-1: Most Appropriate 112 PSAP	Type-2: 112 PSAP + Manuel (or) Auto Ecall PSAP	Type-3: 112 PSAP + Manuel ECall PSAP+ Auto ECall PSAP
Model-1	1	0	0
Model-2	1	1	1
Model-3	1	1	2
Model-4	1	2	5
Model-5	1	7	13
Model-6	1	1	2
Model-7	1	1	2

In case study-3 in Chapter-7, which architectures can be applied as the update or modification of EENA,Model-2 (update of its Figure 5.1 status), "Filtering stage-1 PSAP and resource dispatching stage-2 PSAP" will be analyzed. After the detailed analysis in the Chapter-6 "Cost Model Study", the optimal next generation architecture of current EENA, model-2 applied in the United Kingdom is advised.

5.3.3 EENA Model-3 Architecture Variants After ECall Equipped Vehicle Regulations

According to European Emergency Number Association (EENA) [135], the current and next generation emergency call system of EENA, Model-3 and its response-dispatch variants are analyzed in this Part. Functional description is in Section-1 when section-2 is the technical descriptions. Next, response-dispatch variants (RDV-2 and RDV-3) are emphasized. At the end, the EENA,Model-3 next-generation variant possibilities are summarized. The case study details of EENA, Model-3 which is applied in Romania is not the topic of the thesis. It is not studied in the case-studies due to having low-technological advancements. EENA,Model-1 and EENA,Model-2 investigations in Case studies of Chapter-7 show nearly the same structural case with higher technological advancements.

5.3.3.1 Functional Descriptions of EENA Model-3 Architectures

- Functional Description-1: Current Emergency Call System of EENA, Model-3 via Public Communication

According to European Emergency Number Association (EENA) [135], the current emergency call system of EENA, Model-3 can be described as it is shown in Figure 5.11. In Figure 5.11, EENA, model-3 has a disadvantage that the most appropriate 112 PSAP informs the rescue services directly and it does not care whether the accident is related to the rescue station or not. The civilian call takers classify emergency callings and make the parallel dispatch of the callings to the EROs. The parallel dispatch is not a good service structure due to it does not have any filtration.

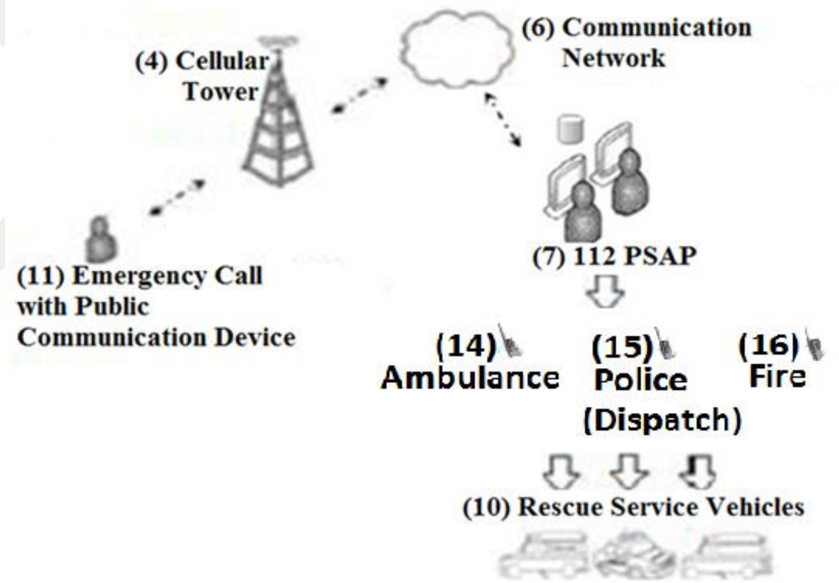

Figure 5.11 EENA, Model-3 General Scenario of Public Communication [143]

The scenario and functional statuses in Figure 5.11 are the same with the Figure 5.7. The difference between them is the parallel dispatch of this structure. The parallel dispatch means the All EROs are informed by 112 PSAP and it does not exist any filtration before sending the data to the EROs.It is not important whether the rescue station is related to the accident or not. Normally EROs (14 and 15 and 16) need to be supported by call-takers; but the call takers in 112 PSAPs (7) are supported by EROs specialist in this EENA, Model-3. As it is emphasized in Part 4.2 and Part 4.3, the call-takers and EROs specialist have an educational level. In this model type, training and educational level of call-takers are at low level.

- Functional Description-2: Current Emergency Call System of EENA, Model-3 via Vehicle Application

The emergency call situation via vehicle application at the current architecture of EENA, Model-3 will be explained in Figure 5.12.

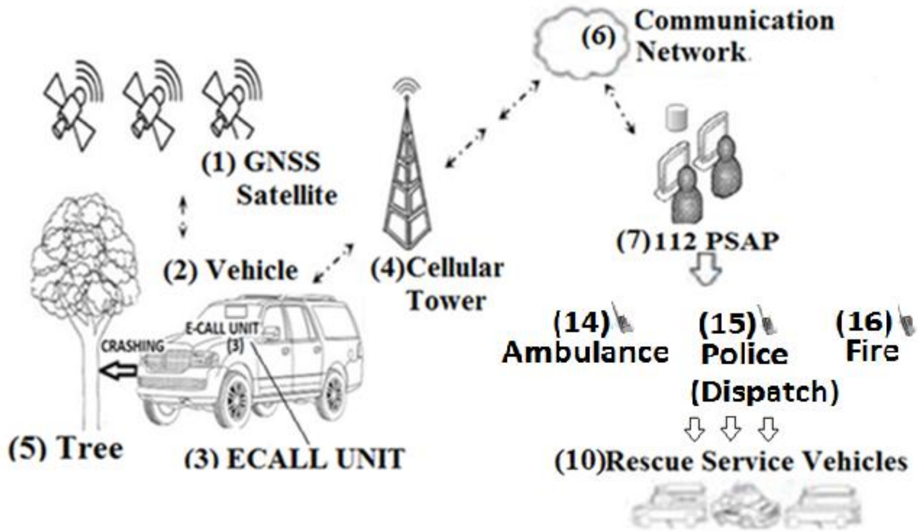

Figure 5.12 EENA, Model-3 General Scenario of Vehicle eCall Process [143]

The scenario and functional statuses in Figure 5.12 are the same with the Figure 5.11. Both are having parallel dispatches (7 to 14 and 7 to 15 and 7 to 16) and the difference between them is only the vehicle applicational stasuss. The vehicles are in usage at the current stasus without any regulation due to testing enviroment; or luxury vehicles can have the eCall system in the accessories. The signal transfer from communication network (6) to 112 PSAP (7) can be in two versions and these are explained in Part 5.3.1.1. It is the same structure also in this manner.

- Functional Description-3: Next Generation Emergency Call System of EENA,Model-3 After eCall Equipped Vehicle Regulations

After the eCall equipped vehicle regulations in 2018, it can have the disadvantages for the countries who uses EENA, Model-3 structure because of the fact that there will be two new types of eCall PSAPs which will be adapted to the 112 PSAP, or created as the new service stations, or will be adapted to the rescue services. Having disadvantages are emphasized because the call takers in EENA,Model-3 are the low-level educated persons and the call management system makes parallel dispatch to the EROs. Because of the parallel dispatch, 112 PSAP is not filtrating the emergency callings whether it is related to the rescue stations or not. The callings are forwarded to the emergency callings to all types of emergency services.

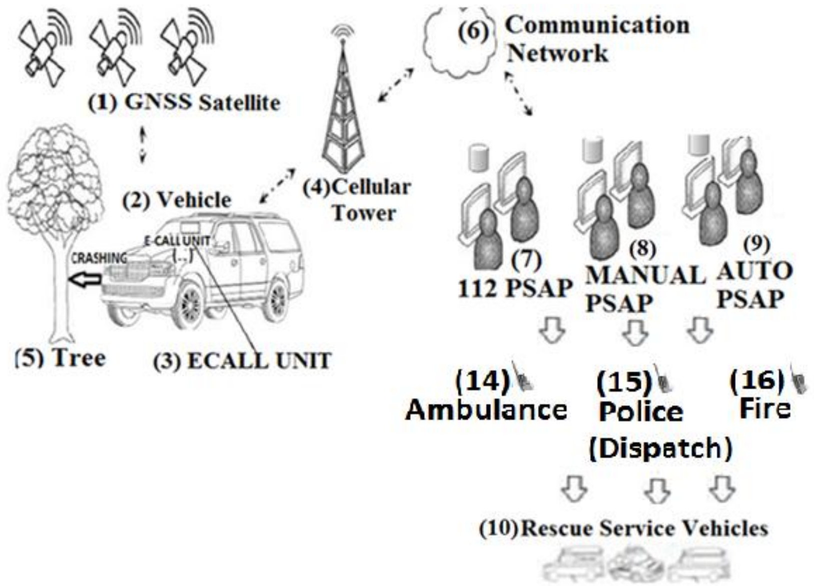

Figure 5.13 Next-Generation EENA, Model-3 General Scenario of Vehicle eCall Process

In Figure 5.13, the Manual eCall PSAP (8) and Automatic eCall PSAP (9) are the new units of the EENA,Model-3 system which is explained in Figure 5.12. After the new eCall units are adapted to the system; EENA,Model-3 needs to create the parallel dispatch structure in eCall PSAPs (8 and/or 9) and they also have the same management software system like 112 PSAP (7). If they added to the 112 PSAP and 112 PSAP is expanded at the same structure, this is enabled. If the eCall PSAPs are created as different service stations, parallel call management system will be created for these station(s). If any of eCall PSAPs are added into the rescue service(s) (-in 14 and/or -in 15 and/or -in 16), they need to have again the parallel call management structure to inform also the other EROs. Its technical structural details will be defined in Part 5.3.2. As a conclusion, it is obvious that the lack of filtration in parallel dispatch system will cause to have unnecessary costs such as Customer Premise Equipment Costs, PSAP Circuit and Facility Costs, Software and Network Costs.

5.3.3.2 Technical Descriptions of EENA Model-3 Architectures

- Technical Description-1: Current ECall System of EENA Model-3

This part explains the data processes of current emergency call system for any public issue with responding calls in Stage-1 PSAP without any filtering process and resource dispatching by Stage-2 PSAP as parallel dispatches. It is in usage in Romania. Its flowchart is the same with Figure 5.10. The only difference is the process 107. In process-107, all rescue service stations (14 and 15 and 16) are informed by 112 PSAP (7). All of three rescue service stations processes & stores the eCall data. The emergency call is forwarded by these services to the rescue service vehicles (10). The difference between EENA, Model-2 and EENA, Model-3 in Figure 5.10 is the EENA,Model-2 has a filtration in Stage-1 PSAP & the emergency case data is forwarded to only related rescue services (14 and/or 15 and/or 16); When EENA,Model-3 does not have a filtration & the emergency case data is forwarded to all recuse services (14 and 15 and 16) parallely.

- Technical Description-2: Next Generation Emergency Call System of EENA Model-3

The technical description of the flowchart for current emergency call architecture of EENA Model-3 is explained in the last section above. In this part, next generation emergency call system structure will be defined for EENA Model-3. The flowchart (200) is defined in Figure 5.6. Every step of flow are the same. The differences in EENA,Model-3 can be summarized with the two items as below:

- The process 216 in Figure 5.6 is different in EENA,Model-3. Because of the parallel dispatch process of Stage-1 PSAP, all rescue service stations are informed by 112 PSAP (process-213) and eCall PSAPs (process-214 and 215). On the other hand, related rescue service station or stations are informed in EENA,Model-1 and EENA,Model-2 because they have higher technological advancement including filtration process of emergency callings in PSAP and they do not use the parallel dispatches.
- 112 PSAP (213 in Figure 5.6) is a different unit from rescue services as it is shown in Functional Descriptions of EENA, Model-3. That means, 112 PSAP is not integrated part of rescue service station and its flow is needed to be varied via its

fitting structure. If the structure change can be applied; maybe, 112 PSAP can be integrated with rescue service stations.

5.3.3.3 Response-Dispatch Variants of EENA Model-3 Architectures

Thanks to new eCall receiving types after the regulations in 2018; the new structure of EENA-Model 3 for call-responses and dispatches are summarized with their variants as RDV-2 and RDV-3 correlations. They have been explained in Part 5.3.1.3.

Taking everything into consideration about RDV-2 and RDV-3 via EENA, Model-3, there will be applicable structures of total 38 architectures will have the availability via the infrastructure of EENA, Model-3 which is applied in Romania. The numbers in gray areas in Table 5.3 below shows the possible applicable architecture numbers of 38 variants for EENA, Model-3. It is the next generation applications including also higher technological applicable architectures via EENA, Models, and eCall receiving types.

Table 5.3 New ECall System Architectures of EENA Model 3 (Author’s Calculations)

EENA Ecall Architectures[16] / New ECall Variants	Type-1: Most Appropriate 112 PSAP	Type-2: 112 PSAP + Manuel (or) Auto Ecall PSAP	Type-3: 112 PSAP + Manuel ECall PSAP+ Auto ECall PSAP
Model-1	1	0	0
Model-2	1	1	1
Model-3	1	1	2
Model-4	1	2	5
Model-5	1	7	13
Model-6	1	1	2
Model-7	1	1	2

The next generation status of EENA,Model-3 is not analyzed in details in Chapter-7 ‘Case Studies’ because of low technological advancements of its structure.

5.3.4 EENA Model-4 Architecture Variants After ECall Equipped Vehicle Regulations

According to European Emergency Number Association (EENA) [135], the current and next generation emergency call system of EENA, Model-4 and its response-dispatch variants are analyzed in this Part. Functional description is in Section-1 when section-2 is the technical descriptions. Next, response-dispatch variants (RDV-4) are defined. At the end, the EENA,Model-4 next-generation variant possibilities are summarized. The case study details of EENA, Model-4 which is applied in Belgium, Turkey, Madrid, Ostrava will be explained in Case Study-2 of Chapter-7 in Part 7.2 based on Turkey Infrastructure.

5.3.4.1 Functional Descriptions of EENA Model-4 Architectures

- Functional Description-1: Current Emergency Call System of EENA, Model-4 via Public Communication

According to European Emergency Number Association (EENA) [135], the current emergency call system of EENA, Model-4 can be described as it is shown in Figure 5.14. In Figure 5.14, a conceptual difference of EENA,Model-4 when it is compared with the other EENA architectures is Unit-17. Unit-17 in Figure 5.14 is the integrated control room/building including 112 PSAP (7) and rescue service(s) (14 and 15 and 16). When the emergency callings reach 112 PSAP in the integrated control room/building (17), its process is procedure at the same infrastructure of rescue services (14 and 15 and 16). At the same facility, giving responses are made by PSAPs and making dispatches are occurred by EROs. This systematical approach is completed in these year periods in Turkey and some of Cities such as Antalya has been completed as ‘Data Gathering by stage PSAP1 and resource dispatching by stage PSAP2 in an integrated control room’.

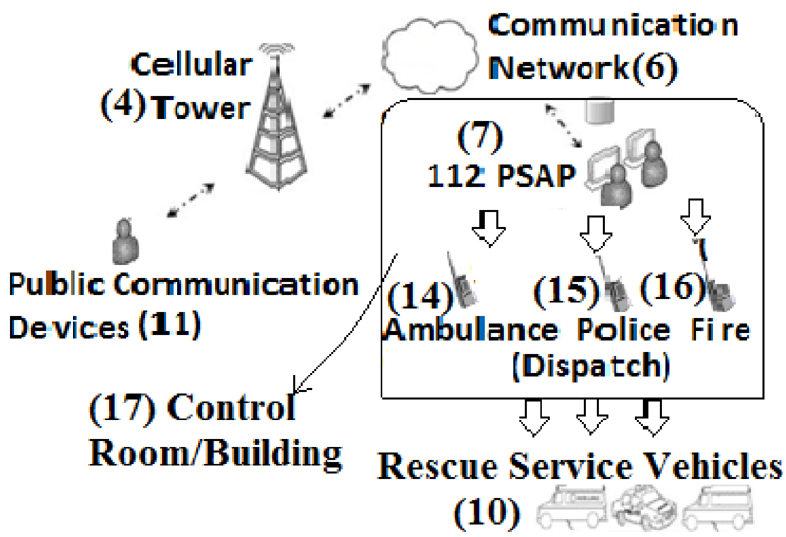

Figure 5.14 EENA, Model-4 General Scenario of Public Communication [143]

Figure 5.14 is the Model-4 in Figure 5.1. Its structural difference with the generic case in Figure 3.1 is the control room/building structure of rescue services and PSAPs. The other parts of the structure are the same as the general scenario. In this structure, 112 PSAP (7) responsible persons have the ability to make dispatch; but they are only giving responses to the emergency callings and forward them to the related ERO(s) (14 and/or 15 and/or 16). That means the PSAP call-takers are middle trained persons in the PSAPs. Dispatchers in the EROs in this structure are also middle-trained persons, they have the response-dispatch abilities but they are making only dispatches to the related rescue team vehicles (10). This is the functional description of current system. To understand the emergency call current status for vehicle application, next part will describe the same architecture status via vehicle application.

- <u>Functional Description-2: Current Emergency Call System of EENA, Model-4 via Vehicle Application</u>

The emergency call situation via vehicle application at the current architecture of EENA, Model-4 will be explained in Figure 5.15.

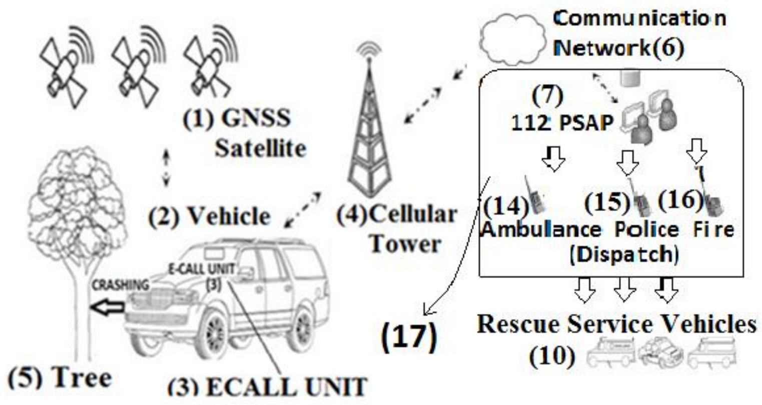

Figure 5.15 EENA, Model-4 General Scenario of Vehicle eCall Process [143]

The scenario and functional statuses in Figure 5.15 is the same with the Figure 5.14. Both are having control room/building structure (7 with 14 and/or 15 and/or 16). The difference between them is only the vehicle applicational status. The vehicle application without any regulation is applied to the same functional flow of Figure 3.2 until unit-7. Next, the emergency calling data in 112 PSAP (7) are forwarded to the rescue services in the same room or building (17) in this architecture in Figure 5.15. After the regulations are applied in 2018, the functional description is emphasized as the part below.

- <u>Functional Description-3: Next Generation Emergency Call System of EENA,Model-4 After eCall Equipped Vehicle Regulations</u>

When the European Union Regulation EU-2015/758 [2] is started to be applied in the European Countries, current emergency call systems will be updated or modified via giving responses to the emergency calls and making dispatches by Emergency Response Organizations (EROs). Figure 5.16 shows the next generation emergency call system with generic EENA architecture of Model-4.

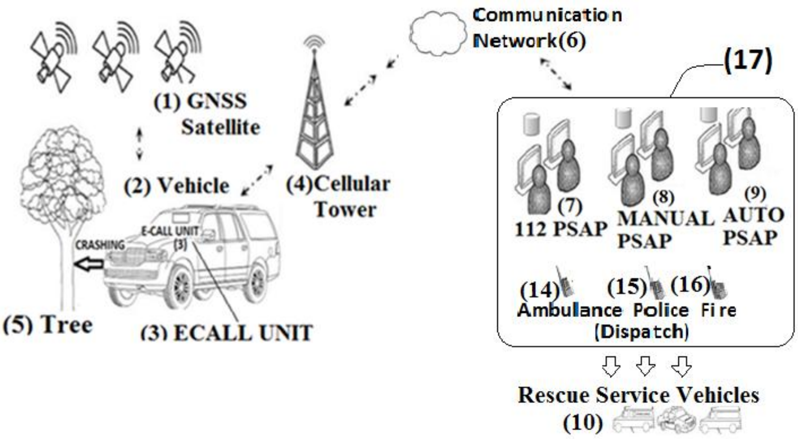

Figure 5.16 Next Generation EENA, Model-4 General Scenario of Vehicle eCall Process

In Figure 5.16, the same scenario with Figure 5.15 about the activation of vehicle eCall unit is used. The process flow until the communication network process (1 to 6) includes the same procedures not only in Figure 5.16 but also in Figure 3.2 and Figure 5.15. After communication network process, the accident data is forwarded to the Integrated control room/building (17) by the communication network; and then it reaches to the 112 PSAP (7) and/or eCall PSAPs (8 and/or 9). At the same PSAP and Rescue Station Facility, the eCall data is processed. There is no external communication process due to being in the same control room/building. It enables to reduce the Customer Premise equipment costs, Network costs, Maintenance costs, and Circuit and Facility costs. This is to say, there is no external network, different maintanence, different infrastructures and terminal circuits. The eCall data is sent to rescue team vehicles (10) by the same control room/building (17) which includes the rescue services (14 and 15 and 16).

5.3.4.2 Technical Descriptions of EENA Model-4 Architectures

- <u>Technical Description-1: Current ECall System of EENA Model-4</u>

This part explains the data processes of current emergency call system for any public issue with responding calls in Stage-1 PSAP with filtering process and resource dispatching by Stage-2 PSAP in the same integrated control room/building which is in usage in EENA,Model-4 countries such as Belgium, Turkey, Madrid, Ostrava. It schemes in Figure 5.17.

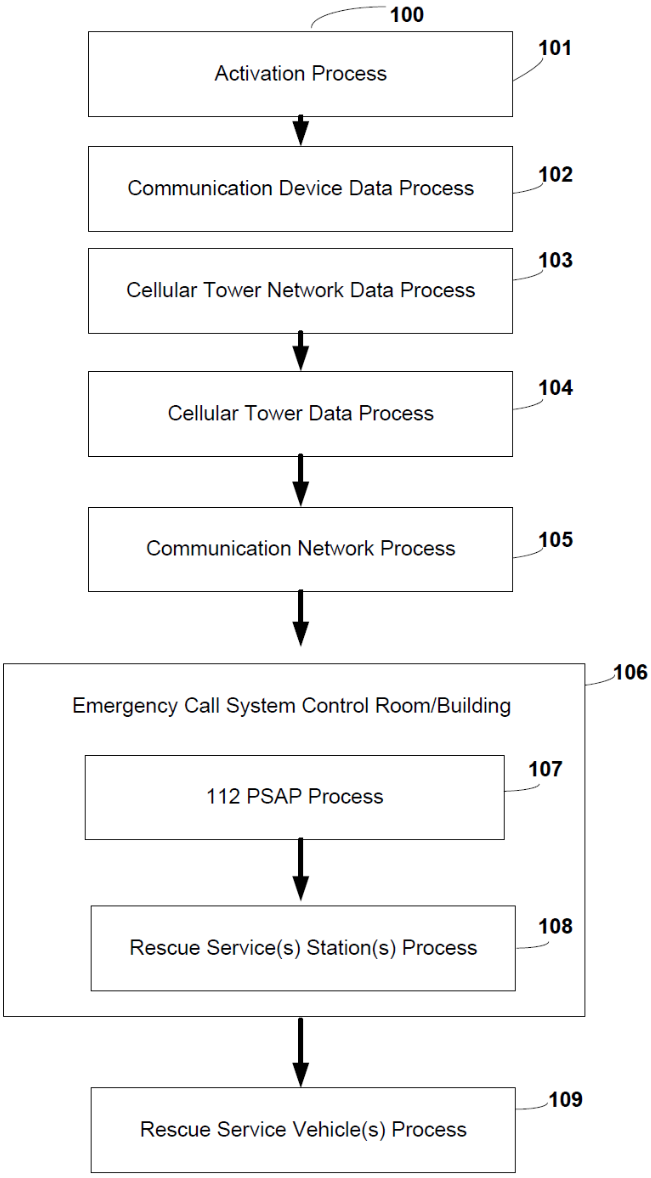

Figure 5.17 Current eCall System Flowchart of EENA,Model-4

Figure 5.17 explains the flow (100) of current status in emergency cases with this type of architecture. The process of activation process (101) and communication network (105) are the same with Figure 5.5 in Part 5.3.1.2.

In Figure 5.17, CTN chooses the available control room/building including 112 PSAP in the related zone (106). 112 PSAP defines the emergency case, processes its data, stores them in its own database and forward them to the related rescue service station(s) which are in the same integrated control room/building (107). Related rescue service(s) uses the same network and facility. They process the data, but they do not need to store the data again. They forward the data to the rescue vehicles (108) via integrated control room/building (106). As it is shown in the process, emergency case data enters the 106 processes. It includes the process 107 and 108.After processes 107 and 108, the eCall data is sent by 106 processes again. Then; rescue service vehicles reach the emergency place (109) with the emergency case data what is enabled by the second-106 process. As it is shown in the process flow (106 to 109), the 106-process occurs two times in the procedure flow due to having integrated control room/building concept. Firstly, eCall data is entered with first 106-process and 112 PSAP works on that. Second 106-process is at the end of the process of the integrated room after 108 processes. Its advantage (106 process surrounding) is the integrated control room concept which enables to use the same network, PSAP Circuit & Facility.

- <u>Technical Description-2: Next Generation Emergency Call System of EENA Model-4</u>

The technical description of the flowchart for current emergency call architecture of EENA Model-4 has explained in the last section above. In this part, next generation emergency call system structure will be defined for EENA Model-4. It will be used in Turkey Infrastructure (Case Study-2 in Chapter-7) after eCall equipped vehicle regulations in 2018. The flowchart (200) is defined in Figure 5.18.

In Figure 5.18, the process of the activation process (201) and communication network process (208) is the same as the process flow in Figure 5.6 of Part-5.3.1.2.

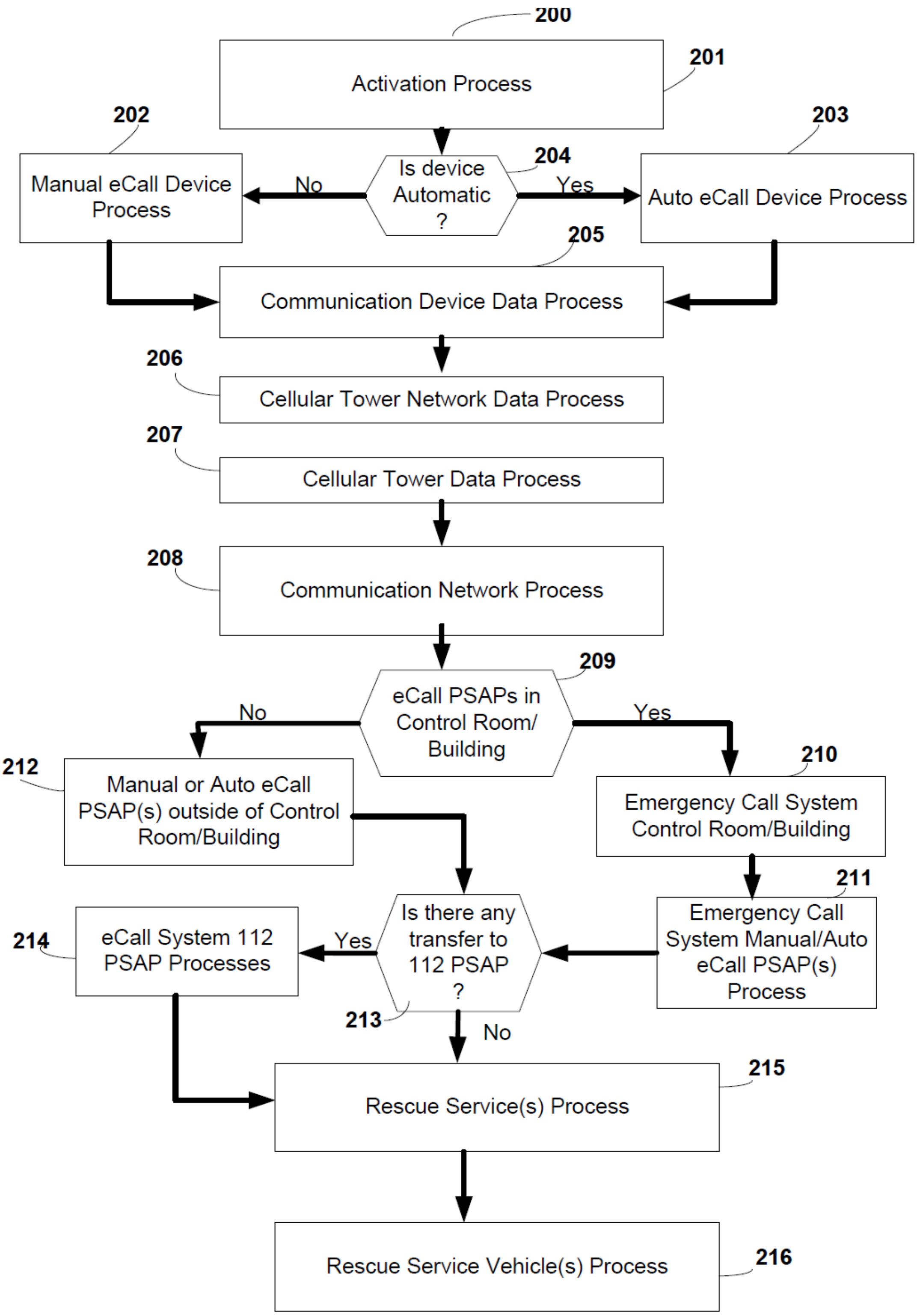

Figure 5.18 Next-Generation eCall System Flowchart of EENA,Model-4

In Figure 5.18, after the output is ready in a communication network (208), PSAPs' process starts. First of all, it is decided whether the PSAPs have control room structure or not (209). If the services are in control room/building, its infrastructure and flows continue at the same room/ building; so the process is explained with 210 and 211. If the service is outside of control room, the process is connected to 212 directly. When the service is chosen whether being 112 PSAP (214), manual eCall PSAP or Automatic eCall PSAP (211-213); the flow continues with rescue service(s) processes. The process 210-211 and process 215 are the infrastructural differences of being integrated control room/building. Process 210 and 211 shows that the ecall PSAPs are in the control/room building if it is not process-212. Process 215 is always in the integrated control room/building whether 112 PSAP and eCall PSAPs in the integrated control room/building or not. That means; the rescue services can be set up with any PSAPs in the same integrated room/building in this structure. After process-215, rescue service(s) make dispatches to the rescue team vehicles on behalf of integrated control room/building facility. Finally, rescue vehicles reach the emergency case place (216).

5.3.4.3 Response-Dispatch Variants of EENA Model-4 Architectures

Thanks to new eCall receiving types after the regulations; the new structure of EENA-Model-4 for call-responses and making-dispatches are summarized with their variants as below:

- RDV-4: Both Response-Dispatch Variants in Control Room/Building

In these structures, Both Response-Dispatch variants in Control Room/Building (RDV-4) means the giving responses to the emergency callings by PSAPs and making dispatches by EROs to the rescue team vehicles can be processed in the same integrated control room/building. In the application (see case-studies in Chapter-7), RDV-4 variants can be applied directly or the other RDV's (RDV-1, RDV-2, RDV-3, RDV-5) can be applied if the EENA, Model-4 country infrastructures are re-organized.

- <u>RDV-4: Both Response-Dispatch Variants in Control Room/Building</u>
  - <u>ECall Response-Dispatch in Control Building Variant-1:</u> There can be 112 PSAP, Manual eCall PSAP, Automatic eCall PSAP and Rescue service stations in the same integrated control room/building. While 112 PSAP responses other public issues, Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. On the other hand, Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but

also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.

- ECall Response-Dispatch in Control Building Variant-2: There can be 112 PSAP, integrated eCall PSAP (manual and automatic together) and Rescue service stations in the same integrated control room/building. While 112 PSAP responses other public issues, integrated eCall PSAP responses the accident issues of vehicles which have manual eCall device and automatic eCall device. On the other hand, Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.
- ECall Response-Dispatch in Control Building Variant-3: There can be 112 PSAP, Manual eCall PSAP and Rescue service stations in the same integrated control room/building. While 112 PSAP responses other public issues, Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. On the other hand, Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.
- ECall Response-Dispatch in Control Building Variant-4: There can be 112 PSAP, Automatic eCall PSAP and Rescue service stations in the same integrated control room/building. While 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. On the other hand, Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.

- ECall Response-Dispatch in Control Building Variant-5: There can be Manual eCall PSAP, Rescue service stations and 'expanded 112 PSAP due to Auto eCalls' in the same integrated control room/building. There is no different Auto eCall PSAP. When 112 PSAP can response not only other public issues but also the accident issues of vehicles which have Auto eCall device; Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. On the other hand, Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.
- ECall Response-Dispatch in Control Building Variant-6: There can be Automatic eCall PSAP, Rescue service stations and 'expanded 112 PSAP due to Manual eCalls' in the same integrated control room/building. There is no different Manual eCall PSAP. When 112 PSAP can response not only other public issues but also the accident issues of vehicles which have Manual eCall device, Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. On the other hand, Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.
- ECall Response-Dispatch in Control Building Variant-7: There can be 112 PSAP and Rescue service stations in the same integrated control room/building when Automatic eCall PSAP and Manual eCall PSAP are outside of control room/building. Automatic eCall PSAP and Manual eCall PSAP are in the same building. While 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. eCall PSAPs forward the emergency callings to the Rescue service stations which are in the same control room/building with 112 PSAP. On the other hand, Rescue Service Stations are making dispatches to the related

rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.

-In this type, another type of the variant can exist. Automatic eCall PSAP or Manual eCall PSAP does not exist and the exist-eCall PSAP which is outside of control room/building give a response to the emergency callings of all accidents of the vehicles including auto eCall device or manual eCall device. The other process and properties about the structure are the same as first type of variant-7.

- ECall Response-Dispatch in Control Building Variant-8: There can be 112 PSAP, Manual eCall PSAP and Rescue service stations in the same integrated control room/building when Automatic eCall PSAP is outside of control room/building. While 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. Automatic eCall PSAP forwards the emergency callings to the Rescue service stations which are in the same control room/building with 112 PSAP and Manual eCall PSAP. On the other hand, Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.
- ECall Response-Dispatch in Control Building Variant-9: There can be 112 PSAP, Auto eCall PSAP and Rescue service stations in the same integrated control room/building when Manual eCall PSAP is outside of control room/building. While 112 PSAP responses other public issues, Automatic eCall PSAP responses the accident issues of vehicles which have automatic eCall device. Manual eCall PSAP responses the accident issues of vehicles which have manual eCall device. Manual eCall PSAP forwards the emergency callings to the Rescue service stations which are in the same control room/building with 112 PSAP and Auto eCall PSAP. On the other hand, Rescue Service Stations are

making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles.

- ECall Response-Dispatch in Control Building Variant-10: There can be Rescue service stations and ‘expanded 112 PSAP due to manual and auto eCalls’ in the same integrated control room/building when Manual eCall PSAP and Auto eCall PSAP do not exist. When 112 PSAP can response not only other public issues but also the accident issues of vehicles which have Auto eCall device or Manual eCall device; Rescue Service Stations are making dispatches to the related rescue team vehicles. In this structure, PSAP responsible persons and Rescue Service Persons are middle-trained level. All service persons know not only giving responses but also making dispatches; but PSAPs give the responses to the emergency callings and Rescue Services make the dispatches to the rescue team vehicles. The variant-10 does not mean the good technological advancements. If the variant-10 is applied, life savings, time cost reductions, accident cost reductions and operating cost reductions cannot be enabled due to its low improved structure.

Taking everything into consideration about RDV-4 via EENA, Model-4, there will be 15 of 38 architectures will have the availability via infrastructure for EENA, Model-4 which is applied in Turkey. Table 5.4 shows the 38 variants with respect to the models and eCall receiving types. The gray areas in Table 5.4 mean the 15 applicable architectures which can be fitted with EENA,Model-4 are produced by these type/model correlations.

Table 5.4 New ECall System Architectures of EENA Model 4 (Author’s Calculations)

EENA Ecall Architectures[16] / New ECall Variants	Type-1: Most Appropriate 112 PSAP	Type-2: 112 PSAP + Manuel (or) Auto Ecall PSAP	Type-3: 112 PSAP + Manuel ECall PSAP+ Auto ECall PSAP
Model-1	1	0	0
Model-2	1	1	1
Model-3	1	1	2
Model-4	1	2	5
Model-5	1	7	13
Model-6	1	1	2
Model-7	1	1	2

In case study-2 in Chapter-7, which architectures can be applied as the update or modification of EENA,Model-4 (in Figure 5.1), "Data Gathering Stage-1 PSAP and resource dispatching Stage-2 PSAP in an integrated control room/building" will be analyzed. After the detailed analysis in the Chapter-6 "Cost Model Study", the optimal next generation architecture of current EENA, model-4 applied in Turkey is advised.

5.3.5 EENA Model-5 Architecture Variants After ECall Equipped Vehicle Regulations

According to European Emergency Number Association (EENA) **[135]**, the current and next generation emergency call system of EENA, Model-5 and its response-dispatch variants are analyzed in this Part. Section-1 will be the functional descriptions, then section-2 gives the technical descriptions, finally response-dispatch variants (RDV-5) are analyzed. At the end, the EENA,Model-5 next-generation variant possibilities are emphasized. The case study details of EENA, Model-5 which is applied in Finland will be explained in Case Study-1 of Chapter-7.

5.3.5.1 Functional Descriptions of EENA Model-5 Architectures

- Functional Description-1: Current Emergency Call System of EENA, Model-5 via Public Communication

EENA, Model-5 can be described as it is shown in Figure 5.19. In Figure 5.19, Unit-7 is 112 PSAP (7) and it is used for not only giving responses to the emergency callings but also making dispatches directly to the related rescue service vehicles (10).

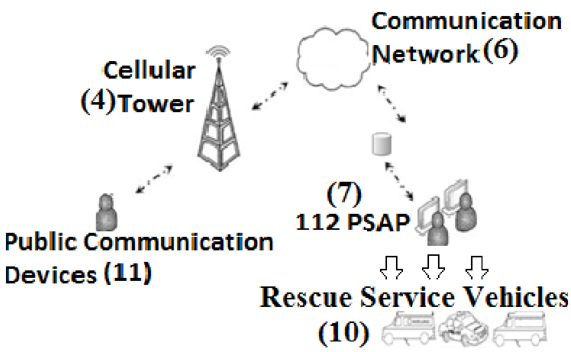

Figure 5.19 EENA, Model-5 General Scenario of Public Communication [143]

Figure 5.19 is the Model-5 in Figure 5.1. Its structural difference with the generic case in Figure 3.1 is the PSAP properties and non-existence of Rescue services stations to make dispatches. The other parts of the structure are the same as the general scenario. There exists most appropriate 112 PSAP (7). This structure is the example of Finland Infrastructure. In this structure, 112 PSAP responsible persons have the ability to give responses to the emergency callings and to make dispatches to the rescue team vehicles. The PSAP responsible persons in this structure are highly trained persons that they can make both processes as response and dispatches. This is the functional description of the current system. To understand the emergency call current status for vehicle application, next part will describe the same architecture status via vehicle application.

- Functional Description-2: Current Emergency Call System of EENA, Model-5 via Vehicle Application

The emergency call situation in this type of application at the current status in Model-5 of EENA Architecture will be explained in Figure 5.20.

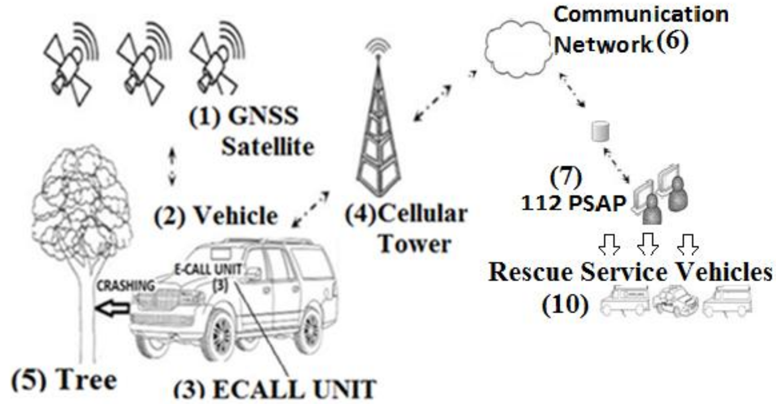

Figure 5.20 EENA, Model-5 General Scenario of Vehicle eCall Process [143]

Figure 5.20 defines the accident case to understand how the emergency cases are processed via vehicle application at the current status in EENA Model-5. The difference between being vehicle application in Figure 5.20 and being a public communicational application in Figure 5.19 is the communication process (6) of receiving signals. The receiving structure via vehicle application in EENA Model-5 at the current status can be the same as the vehicle applicational structure until unit-6 in Figure 5.3 and general structure in Figure 3.2.

These functional definitions enable to understand the current EENA architecture, Model-5; which is applied in Finland (case study-1 in Chapter-7) at the current status. When the eCall equipped vehicle regulations are an obligation in 2018, the system will have the changes. To understand the new architecture generic status and possible changes; general overview will be defined in the next section with Figure 5.21 and its explanation.

- <u>Functional Description-3: Next Generation Emergency Call System of EENA,Model-5 After eCall Equipped Vehicle Regulations</u>

When EU-2015/758 [2] is started to be applied in the European Countries in 2018, the current emergency call systems in EENA, Model-5 will be updated or modified via giving responses to the emergency calls and making dispatches to the rescue team vehicles. Its content is associated with new types of PSAPs and eCall receivings. Figure 5.21 shows the next generation eCall system with generic EENA architecture of Model-5. Its country-specific status will be detailed in Chapter-7 in Case Study-1 for Finland.

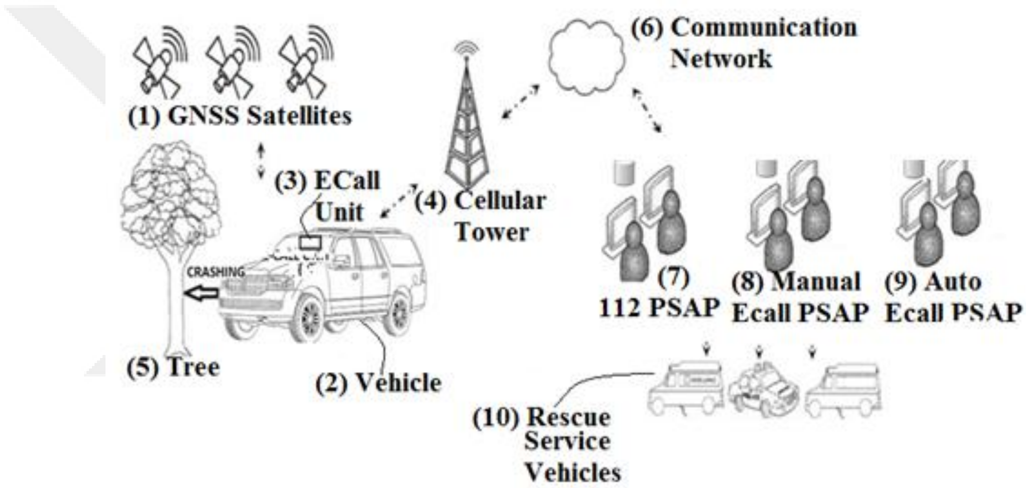

Figure 5.21 Next-Generation EENA, Model-5 General Scenario of Vehicle eCall Process

In Figure 5.21, the same scenario with Figure 5.20 about the activation of vehicle eCall unit is used. The process flow until the communication network process (1 to 6) includes the same procedures not only in Figure 5.21 but also in Figure 5.20. After the accidents data is forwarded by the communication network to the public safety answering points, the process will be varied. The communication network can transfer the emergency call data to the three types of PSAPs (7 and/or 8 and/or 9) in Figure 5.21. These are; (i) 112 PSAP (7), (ii) manual emergency call PSAP (8), (iii) automatic emergency call PSAP (9). According to country infrastructure and system architecture, the accident data can be sent only one of them, two of three answering points or all of them. After the accident data is evaluated by PSAP service(s) (7 and/or 8 and/or 9), it will be sent to the related rescue team vehicles (10) without any process of rescue station(s) (14 and/or 15 and/or 16).

5.3.5.2 Technical Descriptions of EENA Model-5 Architectures

- Technical Description-1: Current ECall System of EENA Model-5

This part explains the data processes of current emergency call system for any public issue with 'ERO Independent PSAP' model which is in usage in Finland. Its flow schemes in Figure 5.22.

Figure 5.22 explains the flow (100) of current status in emergency cases with this type of architecture. The process of activation process (101) and communication network (105) are the same with Figure 5.5 in Part 5.3.1.2.

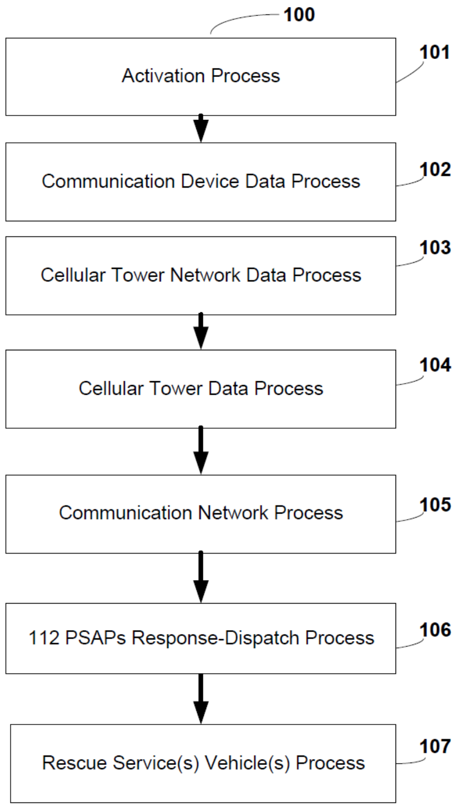

Figure 5.22 Current eCall System Flowchart of EENA,Model-5

In Figure 5.22, CTN chooses the available 112 PSAP at the related zone (105) and 112 PSAP defines the emergency case, processes its data, stores them in its own database and then forward them to the related rescue team vehicles without any process of service station(s). Its call management system, CPE, Network and Facility Circuits are set up not only to give responses to the eCalls but also to make dispatches to the rescue service stations directly (106). PSAPs can be placed in the same buildings or in different buildings when there is no rescue stations. Finally, rescue service vehicles take the required emergency case data, process them and reach to the emergency place (107).

- Technical Description-2: Next Generation Emergency Call System of EENA Model-5

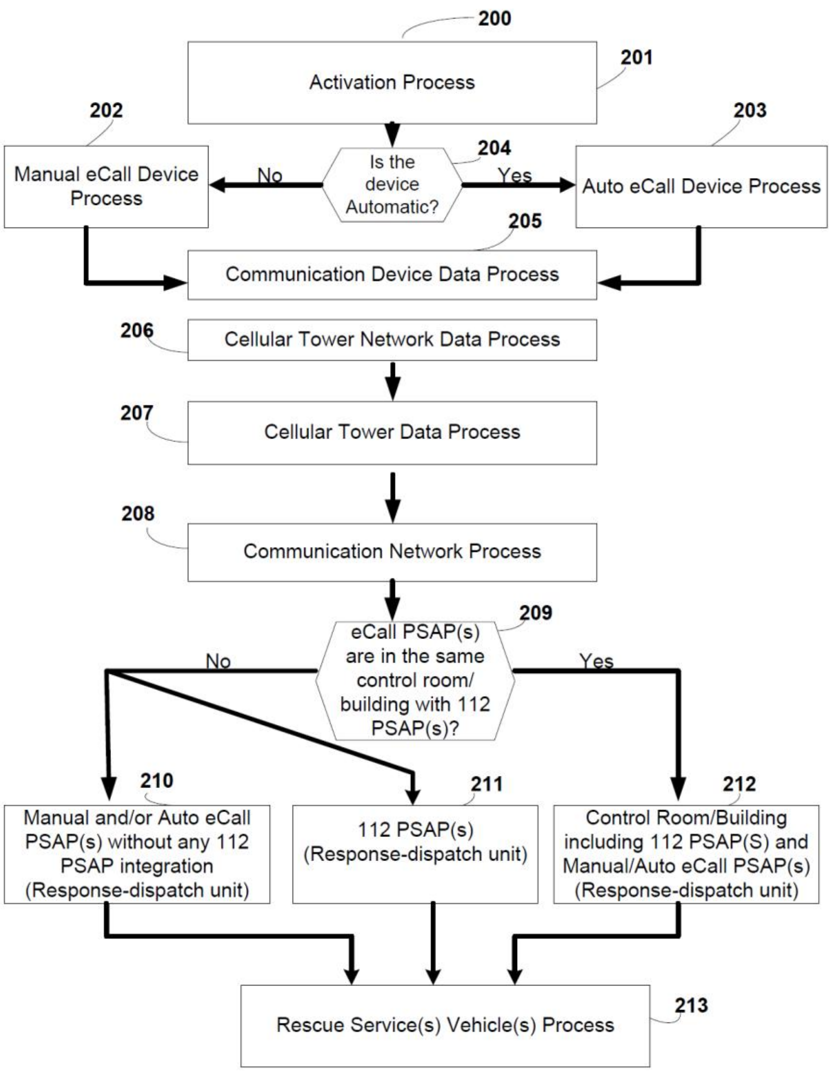

Figure 5.23 Next-Generation eCall System Flowchart of EENA,Model-5

The technical description of the flowchart for current emergency call architecture of EENA Model-5 is explained in the last section. In this part, next generation emergency call system structure after eCall equipped vehicle regulations will be defined for EENA Model-5. The flowchart (200) is defined in Figure 5.23.

The steps of flow between 201 and 208 are the same with the flow of Figure 5.6 in Part 5.3.1.2 . After process-208, the process-209 defines the PSAPs without any rescue service stations whether they are in the same control room/building or not. If eCall PSAPs are in the same infrastructure with 112 PSAP, process 210 and 211 are applied. These are the different units as 112 PSAP and eCall PSAPs. If all PSAPs such as 112 PSAP, manual eCall PSAP and/or auto eCall PSAP are in the same infrastructure (in the same integrated room/building); process-212 is applied. After PSAP processes with '210 and 211', or with '212'; rescue service vehicles are in progress (213).

Its architecture variants due to eCall device types & PSAP types will be studied to understand the optimal next generation status in Chapter-6 'Cost model study' and its comparison results are defined in the Chapter-7 of Case Study-1 for Finland infrastructure which has the current architecture as EENA,Model-5.

5.3.5.3 Response-Dispatch Variants of EENA Model-5 Architectures

Thanks to new eCall receiving types after the regulations; the new structure of EENA-Model 5 for call-responses and making-dispatches are summarized with their variants as below:

- RDV-5: Both Response-Dispatch in PSAP without Rescue Service Stations.

In these structures, Both Response-Dispatch variant in PSAP (RDV-5) means the giving responses to the emergency callings and making dispatches to the rescue team vehicles can be processed by the same PSAP. There is no rescue service station for the dispatch process. In the application (see case-studies in Chapter-7), RDV-5 variants can be applied directly or the other RDV's (RDV-1, RDV-2, RDV-3, RDV-4) can be applied if the country infrastructure is re-organized.

- <u>RDV-5: Both Response-Dispatch in PSAP without Rescue Service Stations:</u>
  - <u>ECall Response-Dispatch in PSAP Variant-1:</u> There can be 112 PSAP, Manual ECall PSAP and Automatic ECall PSAP in the same building. When 112 PSAP responses the emergency cases and making the related dispatches to the rescue service vehicles about public issues without vehicle accident cases, Manual ECall PSAP responses the accident of the vehicles which have Manual eCall

Unit and the same PSAP makes also dispatch processes. Next, Auto ECall PSAP responses the accidents of the vehicles which have Auto (Automatic) eCall Unit and the same PSAP makes also the dispatches. There is no rescue service stations to make dispatches.

- <u>ECall Response-Dispatch in PSAP Variant-2:</u> There can be 112 PSAP, Manual ECall PSAP in the same building and Automatic ECall PSAP does not exist. When 112 PSAP responses the emergency cases and making the related dispatches to the rescue service vehicles about public issues without vehicle accident cases, Manual ECall PSAP responses the accident of the vehicles which have Manual eCall Unit and the same PSAP makes also dispatch processes. There is no rescue service stations to make dispatches.

  -In the same variant, there exists another type. There can be 112 PSAP, Manual ECall PSAP in the same building and Automatic ECall PSAP does not exist. 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about the public issues without accident cases & the accident of vehicles which include auto eCall unit. Next, Manual ECall PSAP responses the accident of the vehicles which have Manual eCall Unit and the same PSAP makes also dispatch processes. There is no rescue service stations to make dispatches.

  -In the same variant, it includes another type. There can be 112 PSAP, Manual ECall PSAP in the same building and Automatic ECall PSAP does not exist. When 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about public issues without vehicle accident cases; Manual ECall PSAP responses the accident of the vehicles which have Manual eCall Unit or Automatic eCall unit and the same PSAP makes also dispatches. There is no rescue service stations to make dispatches.

- <u>ECall Response-Dispatch in PSAP Variant-3:</u> There can be 112 PSAP, Auto ECall PSAP in the same building and Manual ECall PSAP does not exist. When 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about public issues without vehicle accident cases, Auto ECall PSAP responses the accident of the vehicles which have Auto eCall Unit and the same PSAP makes also dispatch processes. There is no rescue service stations to make dispatches.

-In the same variant, there exists another type. There can be 112 PSAP, Auto ECall PSAP in the same building and Manual ECall PSAP does not exist. When 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about the accident of vehicles which includes manual eCall unit and public issues without vehicle accident cases, Automatic ECall PSAP responses the accident of the vehicles which have Automatic eCall Unit and the same PSAP makes also dispatches. There is no rescue service stations to make dispatches.

- <u>ECall Response-Dispatch in PSAP Variant-4:</u> There can be 112 PSAP, Manual ECall PSAP and Automatic ECall PSAP. They can be at the different buildings. When 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about public issues without vehicle accident cases in a different building, Manual ECall PSAP responses the accident of the vehicles which have Manual eCall Unit and the same PSAP makes also dispatch processes. It is also in different place. Next, Auto ECall PSAP in different building responses the accident of the vehicles which have Auto eCall Unit and the same PSAP makes also dispatches. There is no rescue service stations to make dispatches.
- <u>ECall Response-Dispatch in PSAP Variant-5:</u> There can be 112 PSAP, Manual ECall PSAP in the same building and Automatic ECall PSAP can be at the different building. When 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about public issues without vehicle accident cases, Manual ECall PSAP responses the accident of the vehicles which have Manual eCall Unit and the same PSAP makes also dispatch processes. On the other hand, Auto ECall PSAP in the different building responses the accident of the vehicles which have Automatic eCall Unit and the same PSAP makes also dispatch processes. There is no rescue service stations to make dispatches.

In the same variant, there can be 112 PSAP, Automatic ECall PSAP in the same building and Manual ECall PSAP can be at the different building. When 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about public issues without vehicle accident cases, Auto ECall PSAP responses the accident of the vehicles which have Automatic eCall Unit and the same PSAP makes also dispatch processes in the same building with 112 PSAP. On the other hand, Manual ECall PSAP in the different building responses the accident of the vehicles which have Manual eCall Unit and the same PSAP makes also dispatch processes. There is no rescue service stations to make dispatches.

- <u>ECall Response-Dispatch in PSAP Variant-6:</u> There can be 112 PSAP, Manual ECall PSAP at the different buildings and Automatic ECall PSAP does not exist. 112 PSAP responses the emergency callings and making the related dispatches to the rescue service vehicles about public issues without accident cases and about the accidents of vehicles which include auto eCall unit. Manual ECall PSAP responses the accident of the vehicles which include Manual eCall Unit and the same PSAP makes also dispatch processes. There is no rescue service stations to make dispatches.

  -In the same variant, there can be another type. It includes 112 PSAP, Manual ECall PSAP at the different buildings and Automatic ECall PSAP does not exist. When 112 PSAP responses the emergency callings and making the related dispatches to the rescue service vehicles about public issues without vehicle accident cases, Manual ECall PSAP responses the accident of the vehicles which have Manual eCall unit or Automatic eCall unit, and the same PSAP makes also dispatches. There is no rescue service stations to make dispatches.

  -In the same variant, there can be another type. It includes 112 PSAP, Auto ECall PSAP at the different buildings and Manual ECall PSAP does not exist. When 112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about public issues without vehicle accident cases, Auto ECall PSAP responses the accident of the vehicles which have Manual eCall unit or Automatic eCall unit, and the same PSAP makes also dispatches.

  -In the same variant, there can be another type. It includes 112 PSAP, Auto ECall PSAP at the different buildings and Manual ECall PSAP does not exist.112 PSAP responses the emergency callings and makes the related dispatches to the rescue service vehicles about public issues without accident cases and about the accidents of vehicles which include Manual eCall unit. Auto ECall PSAP responses the accident of the vehicles which include Auto eCall Unit and the same PSAP makes also dispatch processes. There is no rescue service stations to make dispatches.

Taking everything into consideration about RDV-5 via EENA, Model-5, there will be 18 of 38 architectures will have the availability via infrastructure for EENA, Model-5 which is applied in Finland. Table 5.5 shows the 38 variants with respect to the models and eCall receiving types. The gray areas in Table 5.5 mean the 18 applicable architectures which can be fitted with EENA,Model-5 are produced by these type/model correlations.

Table 5.5 New ECall System Architectures of EENA Model 5 (Author's Calculations)

EENA Ecall Architectures[16] / New ECall Variants	Type-1: Most Appropriate 112 PSAP	Type-2: 112 PSAP + Manuel (or) Auto Ecall PSAP	Type-3: 112 PSAP + Manuel ECall PSAP+ Auto ECall PSAP
Model-1	1	0	0
Model-2	1	1	1
Model-3	1	1	2
Model-4	1	2	5
Model-5	1	7	13
Model-6	1	1	2
Model-7	1	1	2

In case study-1 in Chapter-7, which architectures can be applied as the update or modification of EENA,Model-5 (in Figure 5.1), "ERO Independent PSAP" will be analyzed. After the detailed analysis in the Chapter-6 "Cost Model Study", the optimal next generation architecture of current EENA, model-5 applied in Finland is advised.

5.3.6 EENA Model-6 Architecture Variants After ECall Equipped Vehicle Regulations

According to European Emergency Number Association (EENA) **[135]**, the current and next generation emergency call system of EENA, Model-6 and its response-dispatch variants are analyzed in this Part. Functional description is in Section-1 when section-2 is the technical descriptions. Next, response-dispatch variants are defined. At the end, the EENA,Model-3 next-generation variant possibilities are summarized. The case study details of EENA, Model-6 which is applied in the Czech Republic, Sweeden, Bulgaria is not the topic of the thesis. It is not studied in the case-studies due to having low-technological advancements. EENA,Model-1 and EENA,Model-2 investigations in Case studies of Chapter-7 show nearly the same structural case with higher technological advancements.

5.3.6.1 Functional Descriptions of EENA Model-6 Architectures

- Functional Description-1: Current Emergency Call System of EENA, Model-6 via Public Communication

EENA, Model-6 can be described as it is shown in Figure 5.24. In Figure 5.24, EENA, model-6 has a disadvantage that the most appropriate 112 PSAPs are connected to each other in the same region and informs the rescue services directly. The civilian call takers classify emergency callings and make the dispatch of the callings to EROs.

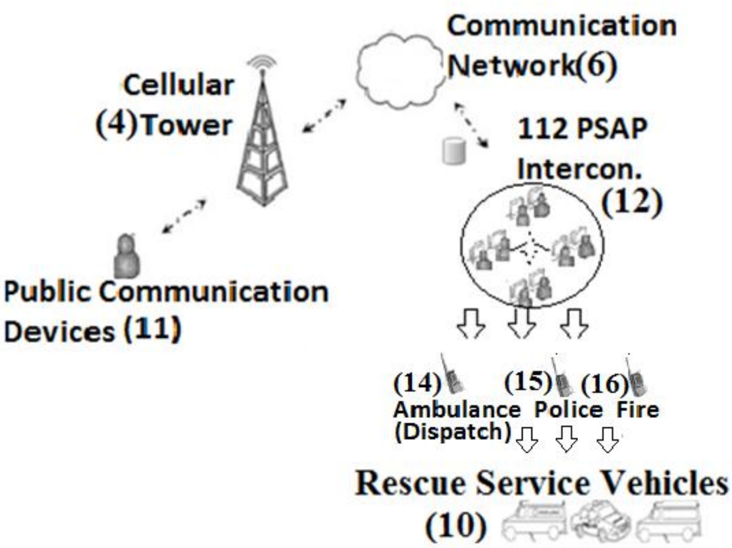

Figure 5.24 EENA, Model-6 General Scenario of Public Communication [143]

The scenario and functional statuses in Figure 5.24 is the same with the Figure 3.1. The only difference between them is the interconnected PSAP structure of this system. The interconnected PSAP means the PSAPs in the same region are connected to each others and they can give responses to the emergency callings if any of them can not response any callings. As it is emphasized in Part 4.2 and Part 4.3, the call-takers and EROs specialist have educational levels. In this model type, training and educational level of call-takers in PSAPs and dispatcher in rescue services are at low level or middle level.

- Functional Description-2: Current Emergency Call System of EENA, Model-6 via Vehicle Application

The emergency call situation via vehicle application at the current architecture of EENA, Model-6 will be explained in Figure 5.25.

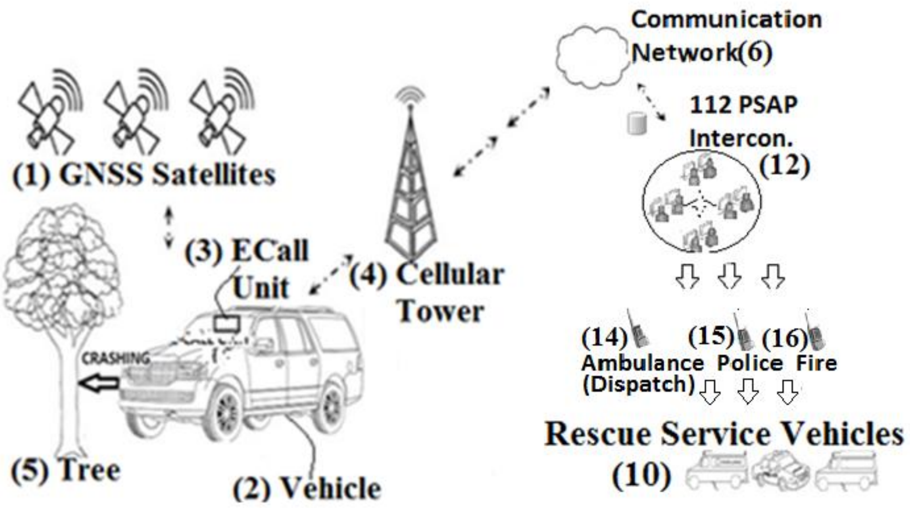

Figure 5.25 EENA, Model-6 General Scenario of Vehicle eCall Process [143]

The scenario and functional statuses in Figure 5.25 is the same with the Figure 5.24. Both are having Interconnected PSAP structures (12) and the difference between them is only the vehicle applicational status. At this side, the signal transfer until the communication network (1 to 6) is the same structure with the Figure 3.2 in the Part 3.2.

- Functional Description-3: Next Generation Emergency Call System of EENA,Model-6 After eCall Equipped Vehicle Regulations

After the eCall equipped vehicle regulations in 2018, there will be two new types of eCall PSAPs which will be adapted to the interconnected 112 PSAPs, or created as the new service stations, or will be adapted to the rescue services.

In Figure 5.26, the Manual eCall PSAP (8) and Automatic eCall PSAP (9) are the new units of the EENA,Model-6 system which is explained in Figure 5.25. After the new eCall units are adapted to the system; because of the interconnected PSAPs structure, eCall PSAPs need to be defined whether they are created as interconnected or not.

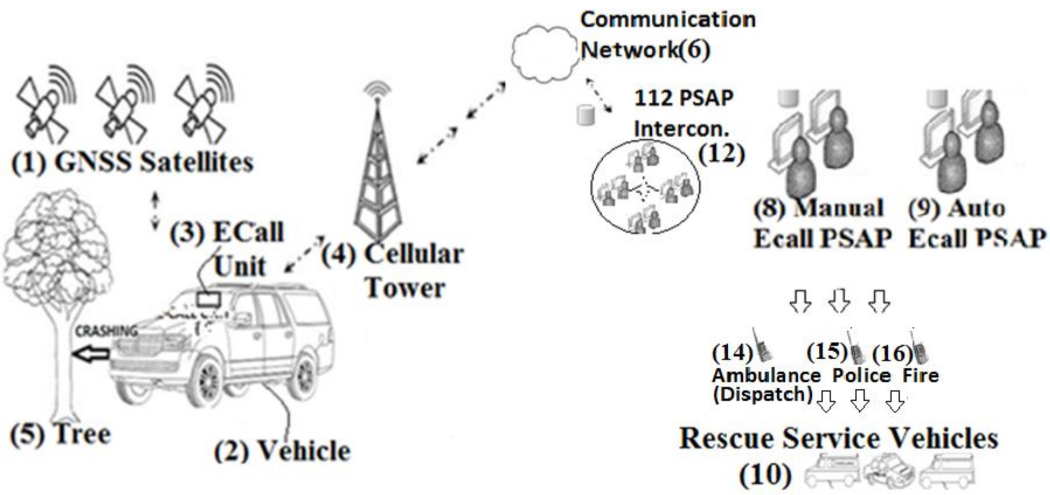

Figure 5.26 Next Generation EENA, Model-6 General Scenario of Vehicle eCall Process

In this point of view; PSAPs can be re-organized with the versions below:

- 112 PSAPs can stay as interconnected PSAPs and eCall PSAPs can be also interconnected PSAPs.
- 112 PSAPs can stay as interconnected PSAPs and eCall PSAPs can be the PSAPs without interconnected structures.
- 112 PSAPs can stay as interconnected PSAPs and Manual eCall PSAPs can be the interconnected PSAPs while Auto eCall PSAPs can be the PSAPs without interconnected structures.
- 112 PSAPs can stay as interconnected PSAPs and Auto eCall PSAPs can be the interconnected PSAPs while Manual eCall PSAPs can be the PSAPs without interconnected structures.

If eCall PSAPs are added to the 112 PSAP and 112 PSAP is expanded at the same structure, this can be also enabled. If the eCall PSAPs are created as different service stations, interconnected call management system will be created for these station(s). If any of eCall PSAPs are added into the rescue service(s) (-in 14 and/or -in 15 and/or -in 16), they need to have again the interconnected call management structure to be in the same network with the other interconnected PSAPs. Its technical structural details will be defined in Part 5.3.2. As a conclusion, it is obvious that this system will cause to have additional costs such as Customer Premise Equipment Costs, PSAP Circuit & Facility Costs, Software and Network Costs due to being interconnected.

5.3.6.2 Technical Descriptions of EENA Model-6 Architectures

- Technical Description-1: Current ECall System of EENA Model-6

This part explains the data processes of current emergency call system for any public issue with responding calls in Interconnected PSAP model which is in usage in Czech Republic, Bulgaria, Sweeden. Its flowchart is the same with Figure 5.10. The only difference is the process 106. In process-106, 112 PSAPs (12) are interconnected and their working principles are different from being most appropriate 112 PSAPs (7). The network and wireless communication requirements of infrastructural works are also more than the other 112 PSAPs (7). This is also disadvantaged for the cost status.

- Technical Description-2: Next Generation Emergency Call System of EENA Model-6:

In this part, next generation emergency call system structure will be defined for EENA Model-6. The flowchart (200) is defined in Figure 5.6. Every step of flow are the same. The differences in EENA,Model-6 can be summarized with the two items as below:

- The process 214 and 215 (in Figure 5.6) are different in this system structure. If the eCall PSAPs (214 and 215 processes) are interconnected with 112 PSAPs (213 process); 213, 214 and 215 processes can be produced as one process. Or; if Automatic eCall PSAP is interconnected to 112 PSAPs, process-213 and 214 can be produced as one process. Or; if Manual eCall PSAP is interconnected to 112 PSAPs, process-213 and 215 can be produced as one process. Or; if Manual eCall PSAP is interconnected to Auto eCall PSAP, process-214 and 215 can be produced as one process.
- The process-213 (in Figure 5.6) in its own structure is different in this system because the PSAPs are interconnected. For instance, one of PSAP can response the emergency calling and another PSAP can forward it to the rescue service stations due to being on the same network.
- The 112 PSAP (213 in Figure 5.6) is a different unit from rescue services as it is shown in Functional Descriptions of EENA, Model-6. That means, 112 PSAP is not integrated part of rescue service station and its flow is needed to be varied via its fitting structure. If the structure change can be applied; maybe, 112 PSAP can be integrated with rescue service stations.

5.3.6.3 Response-Dispatch Variants of EENA Model-6 Architectures

Thanks to new eCall receiving types after the regulations in 2018; the new structure of EENA-Model 6 for call-responses and dispatches are summarized with their variants as RDV-2 and RDV-3, or RDV-4 correlations. They have been explained in Part 5.3.1.3.

Taking everything into consideration about RDV-2 and RDV-3 via EENA, Model-6, there will be applicable structures of total 38 architectures will have the availability via the infrastructure of EENA, Model-6 which is applied in Czech Republic, Sweeden, Bulgaria. The numbers in gray areas in Table 5.6 below shows the possible applicable architecture numbers of 38 variants for EENA, Model-6. It is the next generation applications including also higher technological applicable architectures via EENA, Models, and eCall receiving types.

Table 5.6 New ECall System Architectures of EENA Model 6 (Author's Calculations)

EENA Ecall Architectures[16] / New ECall Variants	Type-1: Most Appropriate 112 PSAP	Type-2: 112 PSAP + Manuel (or) Auto Ecall PSAP	Type-3: 112 PSAP + Manuel ECall PSAP+ Auto ECall PSAP
Model-1	1	0	0
Model-2	1	1	1
Model-3	1	1	2
Model-4	1	2	5
Model-5	1	7	13
Model-6	1	1	2
Model-7	1	1	2

The next generation status of EENA,Model-6 is not analyzed in details in Chapter-7 'Case Studies' because of low technological advancements of its structure.

CHAPTER 6

COST MODEL STUDY

The cost model study in this research is an approach of optimal architecture selection of next-generation EENA,Models after eCall equipped vehicle regulations in 2018; which defines the whole system structures such as eCall equipments of the vehicles, PSAP service structures, emergency service structures. The cost model study can be applied to these kinds of studies in six types. These are; Financial Analysis, Cost-Effectiveness Analysis, Break Even Analyzes, Business Case Calculations, Multi-Criteria Analysis and Benefit to Cost Ratio [121]. The Benefit to Cost Ratio which is the methodology for this study is explained in Part 1.4 ‘Methods’ why the preference method is this.

6.1 Introduction of Cost Model Study: Filtration of Architecture Variants

The current European Emergency Number Association architectures of European Countries are defined in Part 5.1. Then; Future statuses and next-generation improvements are described for next-generation system after eCall equipped vehicles in Part 5.2. Moreover, the architecture variants due to current architectures and next generation receiving types are explained in tables between Table 5.1 and Table 5.6. After these overviews, the next generation architectures of the countries will be defined in Case Studies in Chapter-7. As it is emphasized in these tables and in Chapter-5, there are multitudes of architecture possibilities of current EENA, Models for the countries. These architectures need to be searched via having optimum cost status, optimum service operations and optimum efficiency. This part of thesis will be described how the architecture selections are created for the countries of EENA, Models. Part 5.3 explains the improvements with functional descriptions, technical descriptions, and response & dispatch variants. These logical explanations need to be integrated with the vehicle & road systems and infrastructure systems to create a filtration for the new architecture possibilities. These approaches main functions are explained in Part 6.2. Vehicle systems are analyzed to have a profit with the next generation eCall equipped vehicle systems (see Figure 6.2) and infrastructures are defined to understand how the smart vehicle profits are rated in Benefit to Cost Ratio. Infrastructure system cost includes not only system infrastructures but also vehicle system infrastructure which is eCall component costs (see Figure 6.1). After the detailed analyses of vehicle systems, component system, infrastructure systems; the Country next-generation architectures are reviewed via having the optimal Benefit to Cost Ratio, having optimal Infrastructure Costs and Having optimal overall system costs in the countries.

6.2 Main Functions

Main Functions of the cost model study are analyzed in three sections. These are;

- Vehicle Systems via being smart vehicle or vehicle without smart properties.
- Infrastructure Systems via being optimal architecture or possible architectures.
- ECall Device and Equipment in the vehicle systems after the eCall equipped vehicle regulations.

Firstly, the vehicle systems are defined about its subsystems as below;

- Speed function by road type and vehicle type
- Country Annual Fuel Consumption in the traffic by Country, Road Type and Consumption Year
- Equipment Rates by Equipped Vehicle Stock and Stock Year
- Country Annual Transportation Rate via being good or passenger transportation by year, country and transportation type whether it is good transportation and passenger transportation
- Collision probability by collision type and driver reaction shift forward
- Accident Severity Rates by vehicle speed and accident type
- Road distribution with country-specific data
- Accident Risks per 1 billion km by Country Road Status
- Accident costs by Cost Unit Rates of European Union, Number of Accidents, Accident Severity Rates and Accident Types

- Operating Costs via fixed costs and fuel costs
- Fixed operating costs by fixed cost unit rates via European Union, vehicle mileage and vehicle type
- Fuel operating costs by fuel consumption unit rate, fuel consumption factor and annual road-fuel consumption in the country.
- Time Cost of total transportation (vehicle mileages) and vehicle speed function.
- Emission Costs by Nox Emission and CO2 emission.
- Nox and CO2 emission costs by emission factor, fuel consumption and operating cost unit rate via European Union.

Secondly, the infrastructure systems are defined about its subsystems as below;

- Administrative Costs by Labor costs via EU, training days and number of workers
- Customer Premise Equipment Costs by number of workstations &tax collection fees
- Map and Data Layer Costs by Mapping Software and its Maintenances
- Network Costs by Frame Relay and OEM terminals
- PSAP Facility Costs by unit cost of calls, number of call-events, number of workstations and office costs
- Power supply modules by hardware and maintenance costs
- Wireless Costs by wireless accuracy, databases, and automatic number identification
- Number of PSAPs by number of worker, number of eCall events, type of PSAPs.
- PSAP Training Costs by a number of worker, travel and education expenses.

Thirdly, the eCall device and equipment in the vehicle systems are defined about its subsystems as below;

- ECall device by its unit price, depreciation period and discount rate.
- Equipped vehicle stock by Country and vehicle type.
- Ecall-equipped vehicle effect on the number of PSAP by Country Population, annual eCall events, and vehicle stock.

6.3 Terms and Definitions

Logical approach in cost model study is based on the vehicle specifications (43, 44), eCall component (46) [166] and eCall infrastructural system (45) [167] is shown in Figure 6.1.

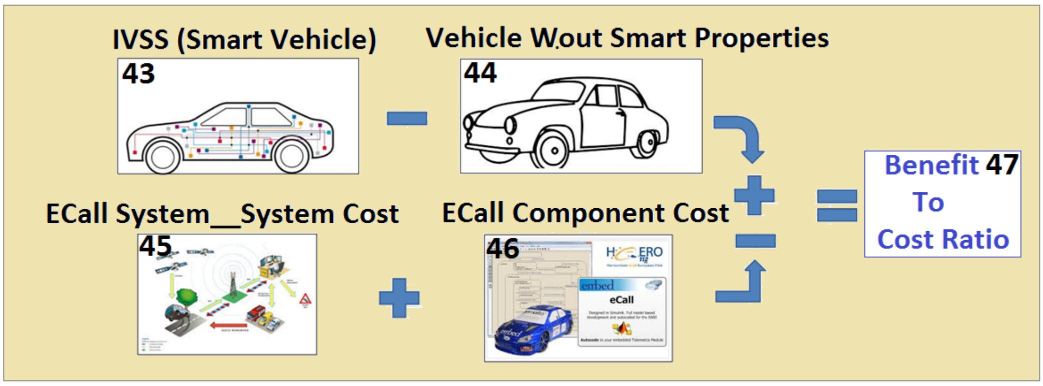

Figure 6.1 General Overview of Cost-Model Approach

In Figure 6.1, Smart vehicle is defined as intelligent vehicle safety system (IVSS) includes the smart technologies for pre-crash, post-crash and crashing items. In this paper, eCall equipment, "post-crashing item" is analyzed and the other smart technologies are emphasized with the equipment rates. Equipment rate is the smart rate of the vehicle which is increased year by year. When equipment rate increases, accidents will decrease.

Cost Model is studied with the main functions which are described in the last section Part 6.2. Its parameters and relational conditions are explained in this part. At the beginning, a whole system overview is explained in Figure 6.2.

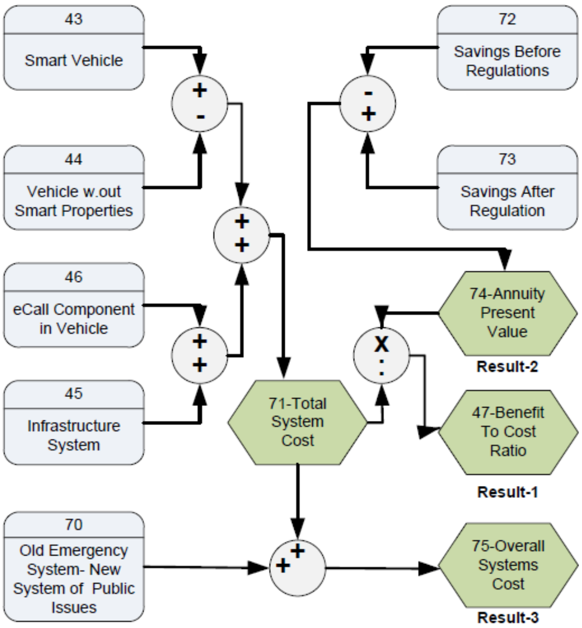

Figure 6.2 Cost Model Overview via the main functions in the System Structure

In Figure 6.2, smart vehicle (43) is described as intelligent vehicle systems when the vehicle without smart properties (44) is introduced to expresses the vehicle costs without the new technologies. The vehicle technology consumption is defined by equipment rate. The new structure of emergency architecture will have the new system requirements and infrastructures; so they are defined as infrastructure system cost (45). Moreover, eCall component in the vehicle (46) is analyzed differently. Emergency Service costs at the current status for public issues (70) are another item to conclude the overall system costs. The difference between savings before regulation (72) and after regulation (73) shows the net benefit of the system (74) described as Annuity Present Value. On the other hand, the sum of the costs in-vehicle system (43, 44) and equipment & infrastructure (45, 46) defines the total system cost (71). The system cost (71) and the current structure cost (or updated emergency services of public issues) (70) defines the overall system costs (75). Finally, Benefit to Cost Ratio (47) which shows the main important result is the function of Annuity Present Value (74) and total system cost (71). Annuity present value (net benefit) is divided by total system cost, and then benefit to cost ratio is found with the depreciation period and discount rate. The results; 74 (result-2), 47 (result-1) and 75 (result-3) in Figure 6.2 will be produced by country-specific results in Figure 7.3, Figure 7.5, Figure 7.8, Figure 7.10 and Figure 7.11 which are the case studies' results in Chapter-7.

In Figure 6.2, the vehicle system (43 and 44) is investigated with the vehicle subsystem which is shown in Figure 6.3 about input-output relations.

Figure 6.3 is vehicle subsystem and it shows the input and outputs. 'I1' is the input1 as transportation. It is the transportation type whether being good carriage or passenger carriage.'I2' is the year when the study is processed such as 2016,2018. 'I3' is the collision type which can be eight types such as rear-end collision, side collision of the vehicle. Driver reaction (I4) is the driver behavior at the accident risk whether the driver can shift its reaction or not. Road types (I5) are the type of ways such as rural, urban, motorway. Country (I6) is the area where this study is applied. Vehicle Type (I7) defines the type of vehicle such as passenger car, light commercial, truck, bus. Accident severity (I8) is the rate of accident risk. Fuel volume (I9) is the fuel consumption in the traffic of the country annually. Fuel Type (I10) is the choice of fuel whether it is diesel or gasoline. Fuel volume type (I11) shows the volume as net volume or gross volume.

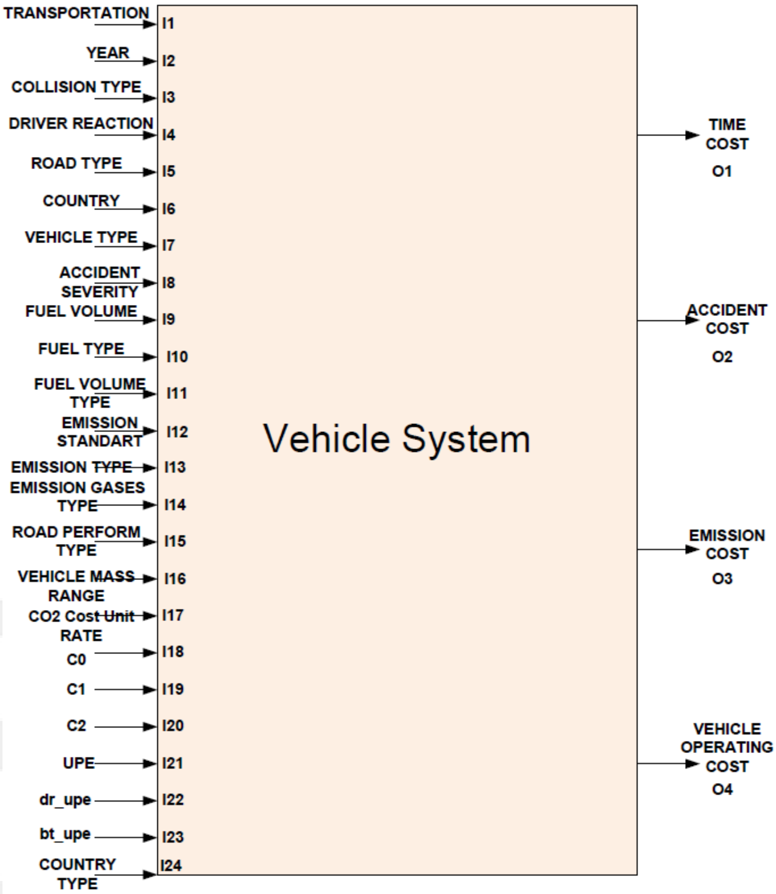

Figure 6.3 Vehicle Subsystem Input-Output Relation

Emission standard (I12) decides the emission between EU-1 and EU-6. Emission type (I13) shows the soot gasses which are Nox or SO2 or PM. Emission Gases' type (I14) describes the CO2 and Nox gases in the emission cost calculation. Road-perform (I15) explains the Country roads which are reviewed as best perform or worst perform in European Union. Vehicle mass range (I16) is the weight categories of passenger cars, light-duty or heavy-duty vehicles. CO2 cost unit rate (I17) is the cost unit of 1 kilogram CO2 when 1 kg fuel burns. c0 (I18), c1 (I19) and c2 (I20) are the Lam formula parameters. Lam formula is the formula for fuel consumption calculation. I18 is the energy efficient parameter when I19 is a drag term of fuel consumption and I20 is ideal fuel rate related to engine capacity. UPE (I21) is the unit price of eCall device in the vehicle. dr_upe (I22) is the discount rate of eCall device price when bt_upe (I23) is the depreciation period of eCall device price. Country type (I24) is the description of the country which is studied in this paper whether being European Country or not.

The outputs of vehicle subsystem in Figure 6.3 are time cost (o1), accident cost (o2), emission cost (o3) and vehicle operating cost (o4). Inputs produce these outputs with internal subsystems. The sum of these outputs creates the total vehicle costs. Moreover, time cost and accident cost are different from being a smart vehicle (43) to being a vehicle without intelligent properties (44).

First of all, vehicle side (43, 44) definitions will be described. General parts of vehicle systems are analyzed in 3 groups and 10 parts in Figure 6.4.

In Figure 6.4, it is the general vehicle sub-systems structure of cost model Figure 6.3. Part 51(accident severity), 56 (time cost) and 54 (accident cost) are different from being "smart vehicle" to being "vehicle without smart technologies". Equipment rate (48) is a yearly rate which shows the vehicle technology about mechatronic-systems based on crash-protections in the intelligent vehicle. When vehicle mileage (49) is a number of transportation whether good or passengers are a carriage, collision probability (50) is the collision-rate decided by accident type and driver reaction. Accident Severity (51) is the percentage-rate defined by vehicle speed and severity types. It shows the importance of accident whether it includes a fatality, severe injury or slight injury. On the other hand, vehicle speed and fuel data (52) exist to calculate the speed function calculations such as operating cost, time cost, and fuel cost. There is a subsystem between real data & statistics and total cost calculations called as "Number of Accident & Road Subsystem" (53).

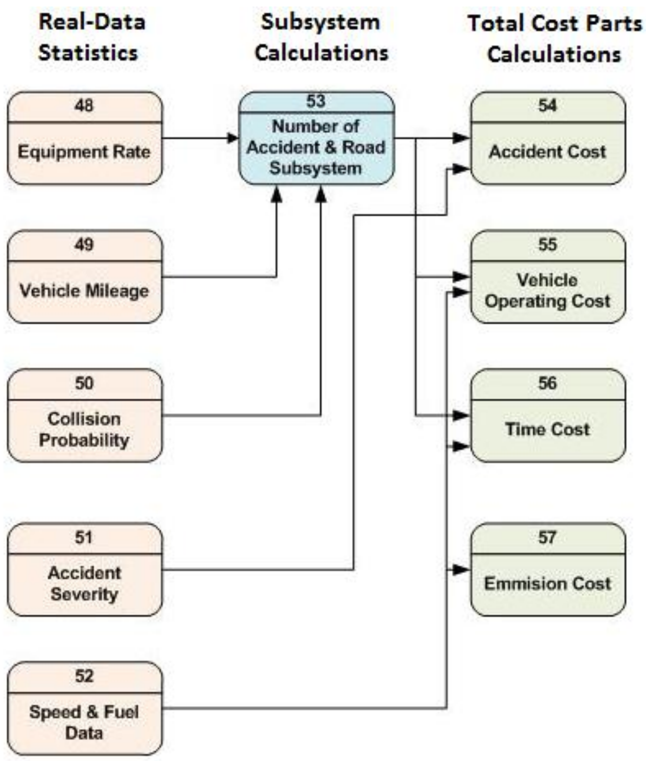

Figure 6.4 General Overview of Vehicle System

Sum of total costs is different between Smart Vehicle (43) and Vehicle without Smart Properties (44) via Vehicle System items in Figure 6.1 and Figure 6.2. This difference produces the benefit side of benefit to cost ratio (BCR). Accident Cost (45) is the function of the subsystem (53) and accident severity (51). Moreover, Vehicle Operating Cost (55) is the functions of subsystem (53) and speed & fuel data (52). When time cost (56) is related to speed, mileage and vehicle type; emission cost (57) is associated with emission standards, road type and fuel type quantity.

In Figure 6.1, ECall component cost (46) and ECall system cost (45) define the equipment and infrastructure cost, which will be the negative side of summation in the benefits process at vehicle calculations. By the way, eCall component cost (46) is the function of eCall devices' unit-price of eCall equipped vehicles and a number of vehicle stock in the related Country. The country-specific data like this data is provided in the Case-Studies in Chapter-7.

In Figure 6.2, the infrastructure system (45) is investigated with the subsystem which is shown in Figure 6.5 about input-output relations.

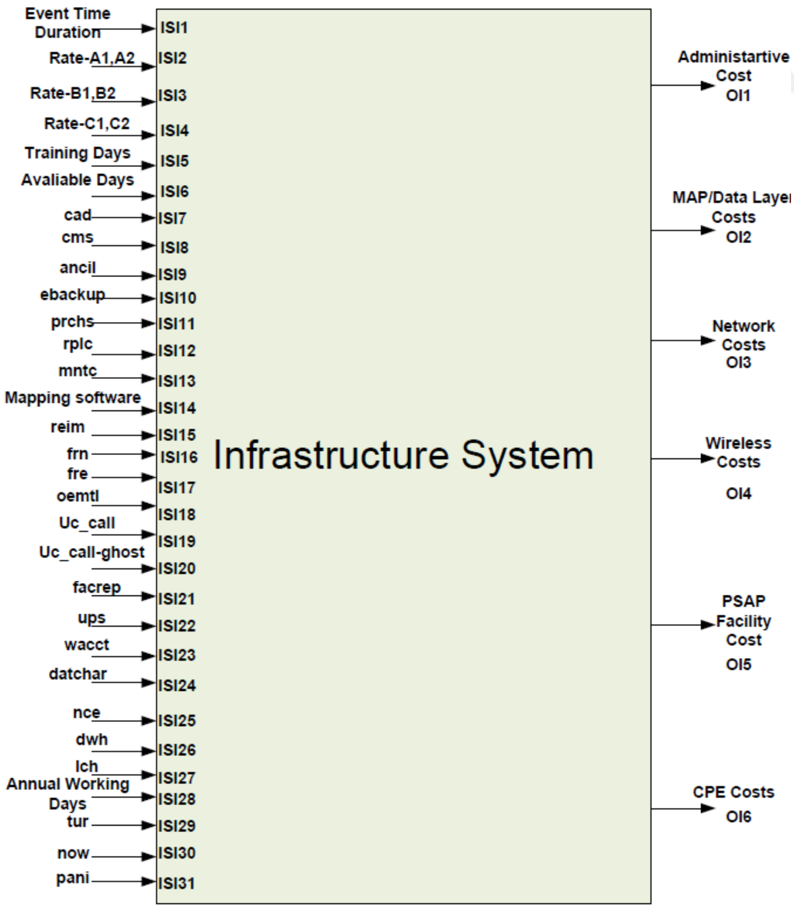

Figure 6.5 Infrastructure Subsystem Input-Output Relation

Figure 6.5 is the infrastructure subsystem including inputs & outputs relation. ISI1 means the infrastructure system input-1 and it defines the event time duration. Event time duration is the time passing when the emergency service responds the callings. ‘ISI2’ rates (A1 and A2) are the filtration rates of small size PSAPs when the population based-number of PSAPs are calculated. ‘ISI3’ rates (B1 and B2) are the filtration rates of medium size PSAPs when the population based-number of PSAPs is calculated. ‘ISI4’ rates (C1 and C2) are the filtration rates of big size PSAPs when the population based-number of PSAPs (see FS8) is calculated. PSAP sizes are explained in the infrastructure section for details (see Table 6.9). ‘ISI5’ is the annual training days when the service workers are trained. ‘ISI6’ is the annual working days of the service workers. ‘ISI7’ is the cad input means the computer-aided dispatch in the rescue services which make the dispatches. ‘ISI8’ is the cms means the call management software input. ‘ISI9’ (ancil) is ancillary equipment when ‘ISI10’ (ebackup) is the input of emergency backup equipment. While prchs (‘ISI11’) describes the purchasing process of the equipment, rplc (‘ISI12’) means the equipment replacements. Moreover, mntc (‘ISI13’) defines the maintenance of the equipment when mapping software (‘ISI14’) is the computer software about the maps which are used by call-takers and dispatchers. Next, reim (‘ISI15’) describes the reimbursement cost of public safety answering points or rescue services. When ‘ISI16’ (frn) is the frame relay costs includes frame relay network and frame relay access, ‘ISI17’ (fre) is frame relay equipment costs and vice versa. ‘ISI18’ (oemtl) is OEM terminal lines. ‘ISI19’ (uc_calls) is the unit call costs of the call-takers and dispatchers. Then, ‘ISI20’ (uc_call-ghost) is the unit call cost of the ghost calls. It means the wrong calls by public issues and eCall devices to the public safety answering points. Uc_call costs are higher than uc_call-ghost costs due to having longer call durations. ‘ISI21’ (facrep) describes the facility replacements when ‘ISI22’ (ups) is the power supply module costs. Next, ‘ISI23’ (wacct) means the wireless accuracy costs and ‘ISI24’ (datchar) is database charges in the PSAP and rescue services. ‘ISI25’ (nce) describes the number of call events which are the callings to the public safety answering points. ‘ISI26’ (dwh) is the daily working hour changing between 8 and 12. Numbers of rescue services to make dispatches are expressed as nrs (‘ISI27’) and a number of public safety answering points to response the callings are defined as np (‘ISI28’).

The outputs of infrastructure subsystem in Figure 6.5 are the administrative cost (oi1), gis/map cost (oi2), network cost (oi3), wireless cost (oi4), PSAP-facility cost (oi5) and customer premise equipment cost (oi6). Administrative costs are the worker costs including salaries and education prices when gis/map costs are the map, data layer and software costs of worker-computer. On the other hand, network and wireless costs are the communication infrastructure costs of services while PSAP-facility costs are the office costs, call-costs. Finally, customer price equipment includes taxes, fees, purchasing-maintenance costs and workstation equipment costs.

The details of vehicle subsystem and infrastructure subsystem are explained in the next sections Part 6.4 and Part 6.5. On the other hand, savings in Figure 6.2 (72 and 73) are the savings of life, reducing congestion timings in the accidents and rescue service timing about being just in time at the accident places. These saving rates change and decrease with the vehicle having smart technologies. Moreover, the reduction of fatalities enables to decrease the accident costs with converting fatalities to the slight or severe injuries. The cost unit rates of fatalities are nearly ten times greater than injuries which show the net benefit for the study. Details will be explained at the Part 6.4 “Vehicle System” and at the Part 6.5 “Infrastructure System”.

The subsystems of Figure 6.5 which is infrastructure system cost (45) are shown in Figure 6.6 with its subsystems.

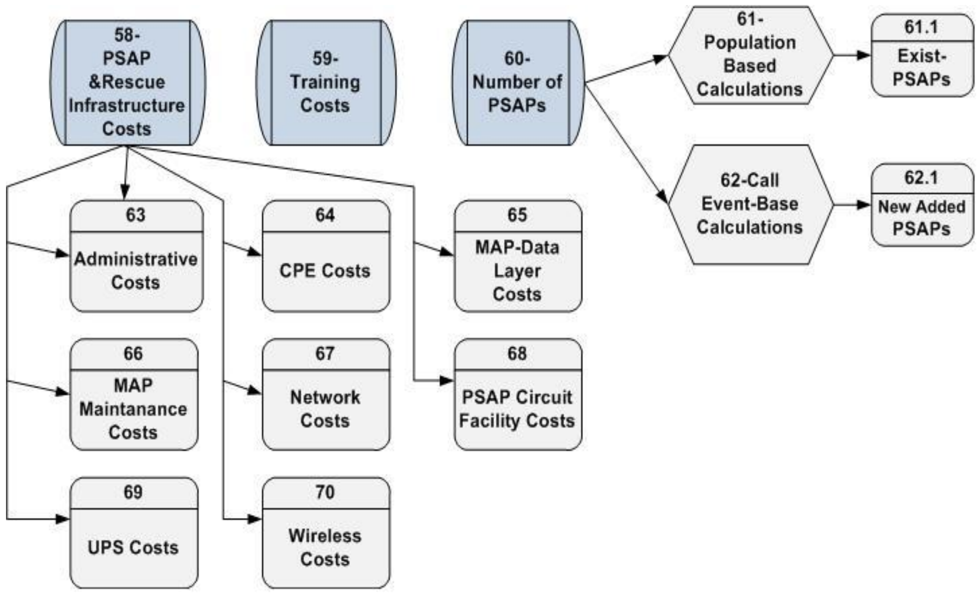

Figure 6.6 General Overview of Overall System Cost with its subsystems

In Figure 6.6, there exist 3 parts in overall system costs as 58 (PSAP &Infrastructure Costs), 59 (training costs) and 60(number of PSAPs). PSAP & Rescue Infrastructure Costs include 8 subsystems which are 63 (Administrative Costs), 64 (CPE Costs), 65 (Map-Data Layer Costs), 66(Map Maintenance Costs), 67 (Network Costs), 68 (PSAP Circuit facility cost), 69 (UPS Costs) and 70 (Wireless costs). Number of PSAPs are analyzed in two groups, 61 and 62. Exist-PSAPs (61.1) are calculated by the population-based process when New Added-PSAPs (62.1) after regulations are calculated by event-base calculations. Administrative Costs (63) are the personal costs when CPE (64) is the customer premise equipment. Map and Data layers (65) are the software programmers in the psap-computers while map maintenance costs (66) are about the psap maintenance services.

Moreover, network costs (67) include all database and charges about frame relay network when wireless costs (70) are about wireless communication network. UPS (69) is the uninterrupted power supply module in which the cost includes hardware and maintenance services. Next, PSAP Circuit and facility (68) are the total events' payments and office costs.

6.4 Vehicle System (43,44)

A General overview of the vehicle system is introduced in the part "Terms and Definitions". Details of the vehicle system in Figure 6.1 and Figure 6.2 will be analyzed in this section.

-Function of I2 and I6 (F1)-

According to being European Union Country and the current model year, the equipment rate is decided. Equipment rate means the rate of vehicle equipment about its intelligent properties. It shows the vehicle technology rate when the autonomous vehicles are thought as having full technology rate. Equipment rates in the vehicle are also explained by ACEA annually in its reports [133], and the author calculates the equipment rate with the vehicle stock is divided by equipped vehicle stock.

Equipment Rate formulation is shown in Formula-6.1.

$$Eq.Rate = \frac{EVS}{VS} * 100 \qquad (6.1)$$

In Formula 6.1, Eq.Rate defines the equipment rate which is the rate of VS divided by EVS. When EVS is the equipped vehicle stock, VS is the general vehicle stock. General vehicle stocks are explained year by year with the updates by ACEA for European Countries. Its rate is explained for EU-25 countries. EU-25 countries are Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, the Netherlands and United Kingdom [168].

Equipped vehicle stock is calculated by the sum of diffusion rate and old registered vehicle stock which means the data a year ago. Diffusion rate in this calculation shows the ratio between intelligent vehicle system and vehicle system without smart properties. This rate is also decided by the Automobile Association which is ACEA for EU.

Moreover, EVS is also calculated with old registered vehicle stock and diffusion rate with the formula-2.

$$EVS = EVS' + dR \qquad (6.2)$$

In formula-6.2, EVS is the equipped-vehicle stock which is the sum of old-registered vehicle stock (EVS') and diffusion rate (dR). The diffusion rate is the rate between intelligent vehicle safety system technology and vehicle without smart technologies rated by the author calculation with the data support of ACEA [133] and Progtrans [169].

Author calculation for EU-25 Countries [168] with the data support of ACEA report is summarized in Table 6.1.

Table 6.1 Yearly Equipment Rates

Model Year	Equipment Rate
2011	23.23
2012	28.93
2013	34.76
2014	40.53
2015	46.64
2016	52.68
2017	58.66
2018	64.58
2019	70.82
2020	76.59

When it is 46.64 percent in 2015, it will be nearly 76.59 percent in 2020 as it is shown in Table 6.1.

- Function of I1, I7 and I24 (F2)-

This is the function of transportation, country and vehicle types which is vehicle mileage. It defines the total transportation rate in the country with the carriage of goods and passengers.

Vehicle mileage (49 in Figure 6.4) defines the good and passenger transportation in European countries. Vehicle types are important to analyze the vehicle mileage. When passenger cars and light commercial vehicles carry the passenger, heavy-duty vehicles and some part of light commercials enable the good transportation. Another important point is the country. Good or passenger transportation is rated country by country with world transport report [169]. In this study, its calculation is measured with the data of EU-25 countries, application year and transportation types.

-Function of I3 and I4 (F3)-

According to the study of Enke Collision Probability [170], the collision probabilities (50 in Figure 6.4) are defined by collision type and driver reaction shift forward. It shows the rate of collision risk for different cases. In the cost-model simulation, minimum and maximum probability scenarios are analyzed. Before defining worst case and best case scenarios, it is important to explain what the collision types are, what the driver reaction is and how they are correlated. First of all, there can be multitudes of collision types when the accident occurs. To be grouped, Transfer Functions in Enke Probability Study are adapted to the technical computing. Enke Probability-function describes the driver reaction shift forward rate between 0 second and 3 seconds [170]. In this range, driver reaction can be in 0.5 seconds for the optimum case when the smallest rate is between 2.5 second and 3 seconds. Normally collision rates are analyzed into 8 groups [121]. These are; (i) Rear End Collision, (ii) Side Collision, (iii) Left Road-Way accidents, (iv) Head-on Collision, (v) Merging and intersection collision, (vi) Vehicle pedestrian collision, (vii) Collision with obstacles, (viii) Other types. In this study parallel to the Enke study, collisions in intersections, oncoming traffic collisions, and rear-end collisions are analyzed in the transfer functions.

The driver reaction shift forward is the drivers' behavior when the accident risk occurs. The driver behavior can be moved between 0 second and 3 seconds in any accident risk and the optimum transfer function can be created in 0.5 seconds [121].

The collision probability is rated between 0.1 % and 75 % in the worst and best case scenarios.

According to Enke Probability rates, the probability can be analyzed between 0 to 3 seconds with three types of collisions. These are a collision in intersection, oncoming traffic-collision and rear end collision. The driver reaction needs to start at least 0.5 seconds. Taking everything into consideration, Table 6.2 shows the minimum and maximum conditions, which are analyzed in cost model study.

Table 6.2 Worst & Best Case Scenarios of Collision Probabilities

Parameters	Minimum Value	Maximum Value
Driver reaction shift forward	3 Sec. (worst)	0.5 sec.(best)
Collision Type	Collision at intersections	Oncoming Traffic Collision
"Transfer Function" Collision Probability	0.001 (0.1 %)	0.75 (75 %)

As a conclusion, collision probability for the minimum and maximum probabilities can be 0.001 and 0.75. When it is thought as percentage, this probability can be between 0.1 and 75 percentages.

The high rate is created by the scenario of collision at intersections with the 3 seconds driver behavior. The low rate is produced by the scenario of oncoming traffic collision with 0.5 second driver behavior.

- Function I8 (F4)-

Accident severity (51 in Figure 6.4) enables the emergency services to understand the accident importance via being fatality or injury. There may be more than one accident in the same area and there can be few rescue service vehicles to send the accident place. This critical rate which is sent by eCall device in the accident-vehicle enables the rescue vehicles to understand the accident severity (see Figure 4.11). Accident severity is the definition of accident importance with respect to being fatality or injury. First of all, accident types will be explained which can be grouped into three sections. These are;

- Accident with Fatality
- Accident with severe injury
- Accident with slight injury

Accident with fatality expresses the high importance accidents when the severe injury explains the middle level importance. On the other hand, slight injuries mean the low-importance accidents. The emergency call unit in eCall equipped vehicle includes the property to detect the accident severity and this info is sent to PSAP. The PSAP forwards the info to rescue services and rescue service understands the accident is critical or not. Then, they prepare themselves via the accident info.

Accident severity is a function of the vehicle speed and vehicle technology. Vehicle speed is investigated between 0 and 130 km/h and vehicle is rated by being a vehicle without smart properties or being a smart vehicle. The investigated accident severities in the scenarios are defined by the author calculation with the data support of e-merge project [171] and the summary is defined in Table 6.3.

Table 6.3 Accident Severity Min & Max Values (Author Calculation with E-Merge Project 2004 [33])

Accident Severity	Smart Vehicle		Vehicle w.out Smart Properties	
	Minimum	Maximum	Minimum	Maximum
Slight Injury Rate	0	1.11	0	1
Severe Injury Rate	0	1.15	0	1
Fatality Rate	0	0.9	0	1

As it is summarized in Table 6.3, Fatality rates can be decreased at maximum rate and other injuries can increase as a worst case. Due to having big cost ratio difference between injury rates, this table shows an advantage because the fatality rate is going down.

The accident severities are decreased year by year when the equipment rates increase which means the technology functions are improved about being pre-crash, crashing and post-crash conditions in the vehicles. This is also summarized in Table 6.3. When the accident severity rates in the vehicle without smart properties are described as 1, smart vehicles are explained with the new accident rates which are created by the speed function and accident types. Accident types are described as being slight injury accident; severe injury accident or accident with a fatality. These types of accidents are looked up into the transfer function with the vehicle speeds between 0 and 130 km/h. The new rates in Table 6.3 show the fatalities can be decreased nearly 10 percent (0.1 rate) when the severe injury and slight injuries can increase due to the decrease in fatalities. On the other hand, injury rates can be stable or can be decreased as a best-case scenario; but, the system is investigated for worst case scenario.

-Function of I5 and I7 (F5)-

In the study, vehicle type and road type enables to define the vehicle speed function with the driving statistics data of Andre' 1999 Study [172]. The vehicle types can be summarized in three groups. These are;

- Passenger Cars
- Light Duty
- Heavy Duty

On the other hand, road types can be grouped in three way-types. These are;

- Rural Roads
- Urban Roads
- Motorways

Taking these types of data into consideration, driving statistics study defines the speed values within Table 6.4.

Table 6.4 Speed Data via Vehicle Type and Road Type

Vehicle Type	Road Type	Speed Data (km/h)	
		Min	Max
Passenger Cars	Rural	39	87
	Urban	23	49
	Motorway	91	109
Light Duty	Rural	39	87
	Urban	23	49
	Motorway	91	109
Heavy Duty	Rural	40	87
	Urban	23	49
	Motorway	76	84

The Case Studies in Chapter-7 defines the country-specific road types and its minimum and maximum values for the vehicle types.

-Function of I9, I10 and I11 (F6)-

Fuel parameters in the study are fuel volume, fuel type, and fuel volume types. Fuel types are summarized with 2 items as below:

- Diesel
- Gasoline

In addition, fuel volume type is described in two sections in the study. These are;

- Net Fuel Volume
- Gross Fuel Volume

Moreover, fuel volume defines the fuel consumption due to road traffics in the Countries. The fuel consumption rates data is provided in the Case-Studies in Chapter-7.

-Function of I1, I5 and I6 (F7)-

The vehicle mileage calculated by ‘F2’ needs to be rated by Country road rates. Road types are described in ‘F5’. Road rates for countries are summarized in Chapter-7 in the case studies for different roads as below:

- Urban way rate in the country as a percentage.
- Rural way rate in the country as a percentage.
- Motorway rate in the country as a percentage.

After the vehicle mileages are rated with these road rates, they can be joined to the output calculations in the ‘O1’ and ‘O4’ in Figure 6.3.

The other parameter created by F7 is the number of accidents. Numbers of accidents are decided by the country whether having good road infrastructures or bad infrastructures. In European Union [121], the road infrastructure divides the countries in three sections. These are;

- Best Perform EU-Countries: Having good road infrastructure
- Worst Perform EU-Countries: Having bad road infrastructure
- EU-Accending Countries’ roads infrastructure

EU-Accending countries are the countries outside of EU-15 countries. According to European Commission Regulations, European Best-Perform Countries’, Worst Perform Countries’ and EU-Accending Countries have the accident risks with the road types as shown in Table 6.5.

Table 6.5 Risks of Number of Accidents

Country	Road Infrastructure	Road Type	Number of Accident Risk Min (Per 1BKm)	Number of Accident Risk Max (Per 1BKm)
EU	Best Perform	Urban	3	5
		Rural	2	5
		Motorway	2	4
EU	Worst Perform	Urban	15	15
		Rural	12	15
		Motorway	9	15
EU-Accending	All	Urban	17	24
		Rural	13	22
		Motorway	10	20

A Number of accident data are provided as country-specific data in the Case Studies in Chapter-7.

Functions (from F1 to F7) in this section enable the calculation of outputs O1 to O4 in Figure 6.3. The Output costs are summarized below.

-Output-1: Time Cost (O1)-

The time cost is a part of total vehicle cost in the vehicle system which is also described in Figure 6.4 as item 56. Vehicle mileage (in F2) and the speed function (in F5) enable the calculation of time cost. The rate of vehicle mileage is divided by vehicle speed function, and then this result is multiplied by the time cost unit rate. The total time-cost is explained in Formula 6.3.

$$TC = \frac{Vm}{v} * TCur \tag{6.3}$$

It is produced by the function of vehicle mileage (Vm in 3) and speed function (v in 3). Vehicle mileage is the output of Subsystem-53 in Figure 6.4 which is road subsystem. After total vehicle mileage is rated by roads, it is entered into time cost as an input to be processed with the vehicle speed which is defined in “Speed and Fuel Data” section. On the other hand, time cost unit rate (TCur in 3) depends on the vehicle type and country information. Its data is rated country by country via vehicle types. The cost unit rates are defined and studied with the author calculation with the data support of Traffic and Road Safety System Report [1].

It means the net output for the time cost is evaluated. The time cost unit rate is the hourly unit cost for vehicle categories.

Time cost unit rates, vehicle mileages which are the country-specific data are enabled in the Case Studies which are in Chapter-7.

-Output-2: Accident Cost (O2)-

Vehicle accident cost in the total vehicle costs which is also described in Figure 6.4 as item 54. It is the function of a number of accident, accident severity and an accident type. Accident cost is the output of the functions F4 and F7. The accident severity in F4 and number of accident in F7 are multiplied with the accident cost unit rate. The accident cost unit rate is the unit cost of one accident via being fatality, severe injury or slight injury. The formula 6.4 gives the result of vehicle accident costs with their embedded functions.

$$VAC = (ACur * As * NoAc) \qquad (6.4)$$

In Formula 6.4, “VAC” is the vehicle accident cost when “ACur” defines the accident cost unit rate (see country-specific data in Chapter-7). ”As” is the accident severity (see Function I8, F4) and “NoAc” is the number of accidents (see Function F7).

Accident cost unit rates which are the country-specific data are enabled in the Case Studies which are in Chapter-7.

-Output-3: Emission Cost (O3)-

Emission Cost inputs are directly calculated in this output subsystem. Emission cost parameters in the inputs of Figure 6.3 are; I7, I9, I12, I13, I14 and I17. Emission costs are calculated by the sum of two parts. These are;

- Nox Cost
- CO2 Cost

The other emission gases (I13) such as PM, non-methane volatile organic compounds are optimized and joined into the Nox gases.

The emission cost calculations are enabled by the multiplication of the parameters below:

- Fuel Consumption Annual Rates (I9 and chapter-7 country data)
- Emission Cost Unit Rate
- Emission Factors and Emission Constant

The Emission cost general formula is explained in Formula 6.5.

$$EC = FC * ECur * Eco * EF \qquad (6.5)$$

In Formula 6.5, EC is the emission cost when FC is the fuel consumption which is the consumed fuel rate in the related-country. FC rates are analyzed in Chapter-7 as country-specific data. Emission constant via fuel type is 9.54 for gasoline and 9.45 for diesel in author calculation with the data support of trading economy agency [196]. ECur is the emission cost unit rate. If it is ECur of NOx gases, it is announced data of the European Commission ExternE programme [173] which defines the cost unit rate of related emission gases.

Emission Cost Unit Rate for NOx gases are provided with European Commission ExternE programme and unit rate for CO2 gases (I17) is 0.205 €/1kg-CO2 [121].

Emission factors are enabled by Emission handbooks [130-132] with the vehicle category (I7), emission standard (I12) and gases types (I14) which are CO2 and Nox in the study.

Fuel Consumption of the country in traffic which is the country-specific data are enabled in the Case Studies which are in Chapter-7.

-Output-4: Vehicle Operating Cost (O4)-

Operating Cost inputs are directly calculated in this output subsystem. Vehicle operating cost parameters in the inputs are; I9, I10, I11, I16, I18, I19 and I20. Vehicle operating costs are calculated by the sum of two parts. These are;

- Basic Operating Cost
- Fuel Consumption Cost

First of all, the basic operating cost is explained. Operating basic costs are the output of the multiplication of two factors as below;

- Fixed Operating cost unit rate.
- Calculated Vehicle Mileage (Chapter-7 Country Data with function F7)

Secondly, fuel consumption cost (FCC in Fo4) is explained. Fuel consumption cost is the output of the multiplication of three factors as below;

- Fuel Consumption Annual Rate of Country (I9 and Chapter-7 Country Data)
- Fuel Consumption Constant
- The function of Fuel consumption factor and fuel cost unit rate

Fuel Consumption constant is the process value without any unit which is 10 in the formulation. The function of fuel consumption factor and cost unit rate is produced by two processes, and then these two processes are summed. These are;

- Fuel Consumption factor is divided by 1 (fuel process-1)
- Fuel Consumption Unit Rate (FCur) (fuel process-2)

Fuel consumption factor which is the denominator of the fuel process-1 is calculated by Lam formula [128-129] and it is associated with the inputs; I18, I19, I20. Fuel consumption factor (Fcf in Fo-5) is calculated by the summation of the parameters below:

- c0 (I18)
- c1 (I19) multiply with the speed function (F5) two times.
- c2 (I20) divided by the speed function (F5).

Fuel Consumption Cost is formulated as in formula-6.6.

$$FCC = \frac{FC * Cco}{FCf} + (FC * Cco * FCur) \qquad (6.6)$$

In Formula 6.6, Fuel Consumption Cost described by FCC when Cco is the Fuel Consumption constant, 10. FCur is the fuel consumption unit rate whose data is decided by two terms. These terms are fuel volume type (net or gross) and fuel type (gasoline or diesel).

FCf in formula-6 is the fuel consumption factor provided by Lam Formula in Formula 6.7 [129].

$$FCf = c0 + (c1 * v\text{^}2) + \frac{c2}{v} \qquad (6.7)$$

FCf in formula-6.7 is the fuel consumption factor is defined by vehicle-type fuel consumption factors c0, c1 and c2. V is the vehicle speed which is explained in the section of “Speed and Fuel data”. c0 is energy efficient parameter with the default value, 30 when c1 is a drag term of fuel-consumption. Its default value is 0.0075. Finally, c2 is the ideal fuel rate related to engine capacity. Its default value can be used as 1598.4 [128]. These are the default vehicle-parameters applicable to all vehicle model-types. As a conclusion, FCC is calculated by constant and variable terms defined in F4 in the simulation.

I18 has the default value as 30 when I19 has the default value as 0.0075. Finally, the default value of I20 is the 1598.4.

On the other hand, Fuel Consumption unit rate is summarized with the Table 6.6 [121].

Table 6.6 Fuel Cost Unit Rates

Fuel Type	Net Fuel Cost (€/Litres)	Gross Fuel Cost (€/Litres)
Gasoline	0.185	-
Diesel	0.189	0.692

Taking all of the output costs into consideration, the vehicle system costs are the sum of four sections below:

- Time Cost (O1 in Figure 6.3)
- Accident Cost (O2 in Figure 6.3)

- Emission Cost (O3 in Figure 6.3)
- Vehicle Operating Cost (O4 in Figure 6.3)

The smart vehicle (43) and vehicle without smart properties (44) in Figure 6.2 are compared about the total costs via these 4 outputs.

In addition to Vehicle Costs, eCall device cost (46) in the vehicle after eCall equipped vehicle regulations are enabled by the multiplication of the terms below:

- Unit price of eCall component (I21 in Figure 6.3)
- Ecall Equipped Vehicle Stock (Function F1)

Ecall equipped vehicle does not mean the equipment rate directly, it is related with Vehicle Stock with eCall properties which will be applied in 2018, and can be estimated for the countries in the data of Function F1. After the multiplication process, these parameters are rated with depreciation period and discount rate, and then the result can be calculated as item-46. Item-46 in Figure 6.2 is the function of total system cost (71) effects the results directly.

6.5 System-Infrastructure Costs (45)

A General overview of the infrastructure system is introduced in the Part 6.3 "Terms and Definitions". Details of –country- infrastructure system in Figure 6.1 and Figure 6.2 will be analyzed in this section. The overall system cost (75 in Figure 6.2) is the summation of total system cost (71) and system costs of public issues (70).

Infrastructure system (45) in Figure 6.2 (also a whole system in Figure 6.5 & Figure 6.6) is the function of total system cost (71) and it is enabled by the multiplication of the terms below:

- Infrastructure System Cost (45.1)
- Number of Services (FS7)

After these two costs are rated with depreciation period and discount rate, the result can be summed with the service training costs (FS10). All these three items will be explained in each section in the part FS10.

Overall Infrastructure System Cost which is described in Figure 6.2 with item-45 is generally formulated in formula 6.8.

$$OISC = \left(\left(\frac{dr*(1+dr)^{bt}}{((1+dr)^{bt})-1}\right)*ISc*np\right)_{\min,\max} + (PTr)_{\min,\max} \qquad (6.8)$$

In Formula 6.8, "OISC" has the meaning of Overall Infrastructure eCall System Cost. The overall calculations are investigated by the minimum (min.) and maximum (max.) values; so the formula is also expressed with min. and max. terms. Next,"dr" is discount ratio which means the present cost value depreciated over the years. The depreciation-year is the term called as "bt" in the calculation. Moreover, "ISc" is the infrastructure system cost when "np" describes the number of PSAP. Finally, "PTr" is the explanation of PSAP training-costs.

In this study, system depreciation period is rated as 8 years with 3 % discount rate.

-Infrastructure System Cost (45.1)-

Infrastructure Costs are the equipment, office and communication costs of public safety answering points and rescue services. Its 7 sections [124] are defined as below:

- Administrative Costs (Function FS2)
- CPE(Customer Premise Equipment) Cost (Function FS3)
- Map-Data Layer & Software Maintenance Cost (Function FS5)
- Network Cost (Function FS6)
- PSAP Circuit & Facility Cost (Function FS4)
- UPS Cost (Function FS4)
- Wireless Communication Costs (Function FS6)

When 112 PSAPs include all these sections at the current status; rescue services, manual eCall PSAPs and auto eCall PSAPs in the next generation notification system will have all of the sections or some of them. It depends on the architecture types.

-Function of ISI1, ISI25, ISI26 and ISI28 (FS1)-

In the available days (ISI6), a number of call events (ISI25) enable to measure the number of PSAP workers and rescue service persons. Its function (FS1 function) is created by the numerator of the function which is the multiplication of two parameters as below:

- Annual number of Call Events (nce, ISI25, see FS9)
- 1 event duration rate (ISI1)

And the denominator of the function which is the multiplication of two parameters as below:

- Annual Working Days (ISI28)
- Daily Working Hour (ISI26 (dwh) between 8 and 12 hour)

An event time duration (ISI1) is rated between 1.5 minute and 2 minutes for the correct calls and its rate is between 0.5 minute and 1 minute for the wrong-ghost calls [123-125]. Annual working days (ISI28) are calculated as the days of the year between 363 and 365 where the system works at all hour. On the other hand, the available working days (ISI6) are different from annual working days. It is the time definition of available working days for one service worker.

The created-function (FS1) is fitted with the correlation between time duration of eCall events hourly and a number of service worker in Table 6.7, and then the conversion by a number of eCall events into the service workers are completed.

Table 6.7 Hourly Call-Event Duration vs. Required Service Worker Relation

Event Time Duration in Hour (ISI1)	Number of Service Worker (FS2)	Event Time Duration in Hour(ISI1)	Number of Service Worker(FS2)	Event Time Duration in Hour(ISI1)	Number of Service Worker(FS2)
0.1-0.6	0	70	7.7	10K	1100
0.61-1.5	1	80	8.8	75K	8250
1.51-2	2	90	10	125K	13750
2-8	2	100	11	350K	38500
13-28	3	200	22	500K	55000
28-40	4	300	33	700K	77000
50	5.5	500	55	800K	88000
60	6.6	1000	110	1M	1100K

Table 6.7 is created by the author calculation with the data support of NENA member state report [123-125]. It enables to find the required number of service workers.

As a conclusion, FS1 function is created by the related numerator and denominator, and then the ratio which is found by this division is rated by Table 6.7 and the required persons are found.

These rescue persons are used in the calculations of;

- Administrative costs (Function FS2)
- Number of PSAPs (FS1 in FS9 for eCall PSAP services, FS1 in FS8 for current emergency services)
- Training Costs (Function FS10)

-Function of ISI5 and ISI6 (FS2)-

The sum of two factors;

- The function of available days (ISI5)
- The function of training days (ISI6)

of the service workers enable to calculate the administrative costs. Each function is enabled by the multiplication of not only available days but also training days for the items below:

- Number of Service Workers (Function FS1)
- Hourly Labor Costs (ISI27,lch [174])
- Available Working Days (ISI6)
- Daily Working Hour (ISI26, dwh)

All of these data are analyzed in the simulation based on the formulas 6.9 and 6.10.

$$Ad1_{\max,\min} = npw * Lc * wh * nad \qquad (6.9)$$

$$Ad2_{\max,\min} = (npw * Lc * wh * ntd) + msc \qquad (6.10)$$

“Ad” is the total administrative costs which include its two portions which are Ad1 and Ad2. “npw” is the number of PSAP workers when “Lc” is the hourly labor cost. ”Lc” data is country specific and it is numbered in Chapter-7 which is published by EU [174]. ”wh” is the working hour which is between 8 and 12 hours per day [175]. Next, ”ntd” is the number of training day and “nad” is the number of available days in a year. Finally, membership prices are called as “msc” and it is country-specific data. Its rates are numbered in Chapter-7 which is published by EU [174].

“npw” in formula 6.9 and 6.10 is calculated by the function in formula 6.11.

$$npw_{\min,\max} = \left(\frac{nce_{yearly}}{yd * dh}\right)_{\min,\max} \qquad (6.11)$$

A Number of PSAP workers is the function of “nce” and “yd”. ”nce” is a number of eCall events and “yd” is the days of the year. In addition, “dh” is the hours of the day. After the numbers of calls are divided by the days, daily calls are found. These eCall-events are divided by day-hours; because the daily call rates are different. After hourly rates are decided, the numbers of PSAP workers are calculated with Table 6.7 by the author calculation with the data support of NENA member-state report [123-125].

Moreover, supervisor of the PSAPs is decided by NENA standards. X-type PSAPs need to have at least 1 supervisor when Y-type PSAPs need at least 2 supervisors. In addition, Z-type PSAPs requires at least 4 supervisors per PSAP. On the other hand, CAD-events can exist in overall 112 PSAPs, eCall PSAPs and rescue services when TIME events might be contented only in overall 112 PSAP or rescue services. CAD is the computer-aided dispatch issues when TIME events are the complaint about wanted persons etc. Total CAD and TIME event numbers are country-specific numbers and they are provided in the case-studies in Chapter-7. CAD and TIME events' rate-calculations to measure the required PSAP-workers are the same logic within the formula-Fo15. These costs are also added to the administrative costs which are contented in "npw" data. By the way, hourly call-duration minimum rates are different for CAD & TIME events, which are defined as: (i) 0.1-0.6 Hour with 0 npw; (ii) 0.61-1.5 Hour with 1 npw; (iii) 1.51-2 Hour with 2 npw; (iv) 2-8 Hour with 2 npw; (v) 13-28 Hour with 3 npw. Moreover, other duration rates for CAD & TIME events are the same within Table 6.7.

Each ISI5 and ISI6 is multiplied by these terms. IS5-calculation enables to calculate the worker-administrative costs and IS6 enables to calculate the worker-training days' costs. In addition, membership prices are also added to them. The membership prices in emergency services are changing country by country and they are provided in the case-studies in Chapter-7. They are calculated by the author calculation with the data support of NENA member state report and European Union Labor cost data [123-125, 174].

Hourly Labor cost (ISI27, lch) is changing country by country in EU database **[174]** and they are provided in the case-studies in Chapter-7. Next, the Daily working hour is rated between 8 and 12. Moreover, available working days are calculated by the difference between the annual working days (ISI28) and the terms below;

- Unpaid off days (sick days etc.)
- Vacation days
- Personal off days
- Training days (Conferences, educations etc.)

In this study, Paid-off days are rated as 10 days when the vacations are 10 days and personal offs are 3 days. In addition, training and educations are rated as 7 days **[136]**.

Administrative Costs (OI1 in Figure 6.5) is used in the calculation of;

- Infrastructure System Cost (45.1)

-Function of ISI25, ISI29 and ISI30 (FS3)-

This function describes the customer premise equipment which includes the sum of the costs below;

- Yearly Fee
- Workstation costs

In addition to these costs, there are also purchasing, replacement, upgrading and maintenance costs; but they are analyzed at “function FS0” section.

Yearly fee is enabled by the multiplication of;

- Tax unit rate (ISI29, tur)
- Total call events (ISI25, nce)

Tax unit rate is rated between 0.6 € and 0.8 € for the whole calls [125]. Total call events are explained in the section “function FS9”.

Workstation costs are enabled by the multiplication of two factors. These are;

- Unit costs of workstation equipment (ISI7,ISI8,ISI9, ISI10)
- Number of workstations (ISI30, now)

The unit cost of workstations includes the price of the workstation equipment which has basically Computer-aided dispatch (cad) ISI7, Call management software (cms) ISI8, ancillary telephony equipment (ancil) ISI9 and emergency backup module (ebackup) ISI10. Their unit costs can be calculated thanks to EENA or NENA member state reports [123-125].

A Number of workstations can be measured by the application conditions such as usage relation between service type, population, and workstation of member state services. In this study, Table 6.8 is created by the author calculation with the data support of NENA standard [134-135] and its membership report [123-125].

Table 6.8 Number of Workstation vs. PSAP Type

Service Size	Population	Number of Workstation
Small Size	0-19000	2-4
Medium Size	19000-100000	5-20
Large Size	100000-140000	21-50

PSAP and Rescue Service sizes and its population relations are explained in the part "function FS7" in details. When there are the workstations between 2 and 4 in small size emergency services, it can be between 5 and 20 in medium size emergency services and can be between 21 and 50 in large size emergency services.

CPE Costs (OI6 in Figure 6.5) is used in the calculation of;

- Infrastructure System Cost (45.1)

-Function of ISI19, ISI20, ISI22, ISI25 and ISI30 (FS4)-

In this part, the annual cost of call events, uninterrupted power modules of the emergency services and the office costs (if there is any new-opened office) are processed. These costs are summed with each other in this subsystem called PSAP Circuit and Facility Costs.

Uninterrupted Power Modules (ups, ISI22) is the power system enables the services to work without any electricity losses. Its costs include;

- Hardware cost
- Maintenance cost

Maintenance cost is analyzed in the section "function FS0", and the hardware cost is the ups, ISI22 cost in the function FS4.

Annual cost is calculated by the function which is the multiplication of;

- Unit cost of correct call (ISI19,uc_call) or unit cost of wrong call (ISI20, uc_call-ghost)
- Total call events (ISI25, nce)

The annual cost of call events is rated between 0.3 € and 0.6 € for the correct calls and it is rated between 0.1 € and 0.2 € for wrong-ghost calls **[177]**. Total call events are explained in the section "function FS9".

Office costs are calculated by the function which is the multiplication of the items below;

- Meter square unit prices in EU per workstation
- Number of workstations (ISI30, now)
- Workstation areas (meter square) in the emergency services

Area unit price per meter square is changing between 400 € and 600 € in EU. Moreover, workstation areas in emergency services are changing via emergency service sizes as below [124]:

- 34 to 76 m^2 per X-Type PSAP
- 85 to 300 m^2 per Y-Type PSAP
- 350 to 950 m^2 per Z-Type PSAP

PSAP Facility Cost (OI5 in Figure 6.5) is used in the calculation of;

- Infrastructure System Cost (45.1)

-Function of ISI14 and FS1 (FS5)-

This is the mapping and data layer costs of software in the computers of call-takers and dispatchers. Its cost function is created by the multiplication of;

- Unit Cost of Map and Data Layers in one Computer (ISI14)
- Number of Service Workers (Function FS1)

Their unit costs can be calculated thanks to EENA or NENA member state reports [123-125, 134-135].

Map and Data Layer Costs (OI2 in Figure 6.5) is used in the calculation of;

- Infrastructure System Cost (45.1)

-Function of ISI16, ISI17 and ISI18 (FS6)-

It is the network cost session and its function is created by the multiplication of the terms;

- Unit costs of network inputs (ISI16,ISI17,ISI18)
- Number of emergency services (function FS7)

  Unit cost parameters (inputs) for network costs are;

- Frame Relay network and monthly access unit cost (ISI16, frn)
- Frame Relay Equipment (ISI17, fre)
- Terminal Lines (ISI18, oemtl)

Their unit costs can be calculated thanks to EENA or NENA member state reports [123-125, 134-135].

Network Cost (OI3 in Figure 6.5) is used in the calculation of;

- Infrastructure System Cost (45.1)

-Function of ISI16, ISI17 and ISI18 (FS6)-

This is the wireless communication includes the sum of costs;

- Wireless accuracy testing (ISI23)
- Database Charges (ISI24)
- Pseudo Automatic Identification Number Charges (ISI31, pani)

These unit costs can be calculated thanks to EENA or NENA member state reports [123-125, 134-135].

Wireless Cost (OI4 in Figure 6.5) is used in the calculation of;

- Infrastructure System Cost (45.1)

-Function of ISI11, ISI12, ISI13 and ISI15 (FS0)-
This is the section of service support costs and it includes the sum of;

- Maintenance (ISI13, mntc)
- Upgrades (inside of ISI12, rplc)
- Purchase Costs (ISI11, prchs)
- Replacements (inside of ISI12, rplc)
- Reimbursement Cost (ISI15, reim)

These costs are the generally grouped-service costs and their contents exist in the parts below:

- @CPE (FS3): ISI11, ISI12 and ISI13 exist
- @MAP and Data Layers (FS5): ISI11, ISI12, ISI13 and ISI15 exist
- @Network Cost (FS6): ISI13 exist
- @UPS Cost (FS4): ISI13 exist

When some function groups (FSs) have maintenance costs, some others have all upgrading, purchasing and maintenance costs. Some functions do not include these service costs.

Service support cost is not used as the output function in the calculation of Infrastructure System Cost (45.1), because it is contented in all functions (in FS2, FS3, FS4, FS5 and FS6).

-Number of Emergency Services (FS7)-

At the current status, 112 PSAPs and rescue services are used to enable the help to the public issues. After eCall equipped vehicles, due to the increase of call events and its different vehicle application status, PSAPs will be varied in three types as 112 PSAP, manual eCall PSAP and Auto eCall PSAP. The number of PSAP calculations can occur in two types. These are;

- Population-Based Current PSAP Calculation (FS8)
- Call Event-Based eCall PSAP Calculation (FS9)

Before defining these Calculation types, emergency services will be introduced. Emergency services can be (see Part 4.2 and Part 4.3 for the details);

- 112 PSAP (Answering Point)
- Manual eCall PSAP (Answering Point)
- Automatic eCall PSAP (Answering Point)
- Police Rescue Services (Rescue and/or Dispatch Point)
- Ambulance Rescue Services (Rescue and/or Dispatch Point)
- Fire Rescue Services (Rescue and/or Dispatch Point)
- One Unit Rescue Service for Dispatch Process (Rescue and/or Dispatch Point)
- Integrated Control Room with different types of units (Rescue and/or Dispatch Point)

According to NENA standards [134], PSAPs can be varied in three types as shown in Table 6.9.

Table 6.9 PSAP Types via sizes

Population	PSAP Type	PSAP Acronym
0-19000	Small Size	X
19000-100000	Middle Size	Y
100000-140000	Large Size	Z

Rescue services can also set up with the same logic if necessary. But, at the current status; there exist rescue services (Rescue Points). If the dispatch point is not in the rescue service and it is not adapted into the PSAP or integrated control room; there can be new office for dispatchers as one unit or more than one unit. It depends on infrastructure status.

Before defining the calculation FS8 and FS9 sections, it is also important to describe the number of PSAP workers via PSAP Types which is shown in Table 6.10. It is the author rates with the data support of NENA Standards [134] and Its Member State Report [124].

Table 6.10 Number of PSAP Workers vs. PSAP Types

PSAP Type	Unit Number of PSAP Worker Acronym	Minimum Persons	Maximum Persons
Small	X1	7	11
Middle	Y1	12	20
Large	Z1	21	50

Before the calculations, finally, the data of country populations need to be defined. It is the country-specific data, so it will be defined in the case studies which are in Chapter-7.

-Population Based Current-PSAP Calculation (FS8)-

Normally, the current PSAPs in the countries are obvious in the formal documents in the Country Governments. It can be loaded to this study from formal documents of governments. But, the current PSAP calculation enables to see the range of the current number of PSAPs in 3 sigma (3 sigma is the approach of 6 sigma tool [127]). Then, this calculation is re-calculated after the new eCall PSAPs join to the system. The new rates enable us to see whether the PSAP rates are again inside of the 3 sigma boundaries.

After understanding the aim of this calculation (FS8), population-based calculation can be described what it is.

In FS8 calculation, the process of the calculation flow (process flow; PF) is explained as below:

- PF-1: Country Population is saved (see Case Studies in Chapter-7)
- PF-2: Country Population is divided into the population parts with the city and county rates. (Look at Table 6.11)

  County is the city population with the rate of medium size PSAPs. These city and county rates define the spaces in which the PSAPs with the different sizes are built up. PSAPs are introduced in Table 6.9 as three types. In this process, the country population is rated with the separated populations to understand how many PSAPs are needed.
- PF-3: After the country population is separated to the population groups in the Table 6.11, these populations are coded. (See the code-letters in Table 6.11; 3rd and 6th Columns)

- PF-4: Thanks to these code letters, all the populations are written as the equations with the code-letters of A (X), B (Y) and C (Z) which are the PSAP Types-populations in Table 6.9. There are many code variants to be applied in one code-letter. As an example, one code-letter variant are given in Table 6.11. (2nd and 5th Columns)
- PF-5: Then, the unit-population groups in Table 6.11 which is the code-letter equations are applied to the whole country population. The country population is written with the code-letters in Table 6.12 (see also Table 7.1, Table 7.3, Table 7.9, Table 7.13 and Table 7.17 for case-study countries). The example code-letter variants in "Table 6.11" which are converted to the A, B, and C population purely are multiplied with the existing population numbers (Number of Population Size-Rate) of the country. Then, the results of how many A, B and C are created for the country are shown in Table 6.13.
- PF-6: This is to say, in Table 6.13 (see also Table 7.2, Table 7.4, Table 7.10, Table 7.14 and Table 7.18 for case-study countries), it is understood how many PSAPs exist in the country. But these rates give the wrong results. Because the countries in every '0-19000 population' or '19000-100000 population' or '100000-140000 population' does not include the PSAP. Some small populations are combined with the big size populations such as villages can be combined to the cities for PSAP processes. So the PSAP numbers can be decreased. These results are filtrated with the filtration rates A1, B1, C1 and A2, B2, C2 to have the correct numbers.
- PF-7: A1, B1, C1 are the filtration rates of the minimum number of PSAPs when A2, B2, C2 are the rates of a maximum number of PSAPs in the author calculations.
- PF-8: A1, B1, C1 and A2, B2, C2 rates enable the population calculation to be in 3 sigma interval of the 6 sigma rules. These rates are calculated by the author with the support of six sigma rules; and it is measured in Matlab/Simulink environment, and then it is validated with the current number of PSAPs in the country. Then it is applied to the study.
- PF-9: A1, B1, C1 and A2, B2, C2 rates are defined in Table 6.14.
- PF-10: After the number of A is multiplied with A1 and A2 ; the number of B is multiplied with B1 and B2; the number of C is multiplied with C1 and C2; the results are given as function FS8 with the minimum and maximum values, which means the current PSAP rates minimum and maximum values in 3 sigma of 6 sigma rules.

Table 6.11 Population Rate Definition with the Code-Letters and ItsVariants

Population Size	PF-4 ; Example Code-Letter Variant	Code-Letter	Population Size	PF-4 ; Example Code-Letter Variant	Code-Letter
0-19000	A	A	1.6M-1.8M	2A+7B+8C	L
19K-100K	B	B	1.8M-2M	4A+6B+10C	M
100K-140K	C	C	2M-2.5M	4A+8B+11C	N
140K-240K	B+C	D	2.5M-3M	4A+9B+13C	O
240K-340K	2B+C	E	3M-3.5M	4A+12B+16C	P
340K-500K	2A+B+2C	F	3.5M-4M	4A+15B+19C	R
500K-750K	3B+3C	G	4M-4.5M	6A+14B+21C	S
750K-1M	2A+2B+5C	H	4.5M-5M	6A+19B+24C	T
1M-1.2M	2A+4B+5C	I	5M-6M	8A+24B+26C	U
1.2M-1.4M	6B+6C	J	6M-7M	8A+24B+32C	V
1.4M-1.6M	2A+5B+8C	K	7M-8M	8A+30B+38C	Y

Table 6.11 shows the code-letter definition with unit population rates via Code-Letter. If the process flow is remembered; in PF-3, it means the code letters which are the 3rd column and 6th column in Table 6.11. PF-4 means the populations are re-written via unit population which means the 2nd column and 5th column in Table 6.11. The example variant can be written with the different code variants. It shows the logical approach and one application how it can be characterized.

After understanding of Table 6.11, the existing populations in the processed-country with the population rates and code-letters are given in Figure 6.12 (see also Table 7.1, Table 7.3, Table 7.9, Table 7.13 and Table 7.17 for case-study countries)

This is to say, the country includes the population groups via sizes in 2nd columns and 5th columns. If the process flow is remembered; in PF-5, it means the code letters (3rd column and 6th column) are associated with the 2nd column and 5th column in Table 6.12 which are sequenced in the country population.

Up to now, Unit Population rates with the code letters are defined and the country Populations are re-written by Code Letters how many population groups the country has.

Table 6.12 Country Population-Separations with the Code-Letters

Population Size	Existence in the Country (Number of Population Size Rate)	Code-Letter	Population Size	Existence in the Country (Number of Population Size Rate)	Code-Letter
0-19000	@ Chapter-7	A	1.6M-1.8M	@ Chapter-7	L
19K-100K	@ Chapter-7	B	1.8M-2M	@ Chapter-7	M
100K-140K	@ Chapter-7	C	2M-2.5M	@ Chapter-7	N
140K-240K	@ Chapter-7	D	2.5M-3M	@ Chapter-7	O
240K-340K	@ Chapter-7	E	3M-3.5M	@ Chapter-7	P
340K-500K	@ Chapter-7	F	3.5M-4M	@ Chapter-7	R
500K-750K	@ Chapter-7	G	4M-4.5M	@ Chapter-7	S
750K-1M	@ Chapter-7	H	4.5M-5M	@ Chapter-7	T
1M-1.2M	@ Chapter-7	I	5M-6M	@ Chapter-7	U
1.2M-1.4M	@ Chapter-7	J	6M-7M	@ Chapter-7	V
1.4M-1.6M	@ Chapter-7	K	7M-8M	@ Chapter-7	Y

At the moment, as it is described in PF-5, the country population via A, B and C can be defined in Table 6.13. In Table 6.13, the country population is evaluated with A, B, and C code letters. All other code-letters (in Table 6.12) are also converted to A, B and C code letters.

Table 6.13 The Country Whole Population with the Code-Letters of A,B,C

PSAP Type	Population Size	Existence of A,B,C Populations in the whole Country Population	Code-Letter
X	0-19000	@ Chapter-7	A
Y	19K-100K	@ Chapter-7	B
Z	100K-140K	@ Chapter-7	C

Normally, the PSAP numbers are obvious for the country at the current statuses in Table 6.13 (see also Table 7.2, Table 7.4, Table 7.10, Table 7.14 and Table 7.18 for case-study countries). But, as it is emphasized between PF-6 and PF-8; the filtration rates in Table 6.14 are applied to PSAP numbers of Table 6.13.

Table 6.14 Filtration Rates vs. Values for Population-Based Calculations

A1	A2	B1	B2	C1	C2
0.12	0.204	0.205	0.04	0.675	0.92

Finally, the filtration rates in Table 6.14 are multiplied with the values in table 6.13 (also in Table 7.2, Table 7.4, Table 7.10, Table 7.14 and Table 7.18 for case-study countries) values as shown below and PSAPs can be configured.

- X multiply with A1 and X multiply with A2
- Y multiply with B1 and Y multiply with B2
- Z multiply with C1 and Z multiply with C2

Its formulation is saved as Formula-6.12 and Formula-6.13.

$$n112p_{\max} = (nX * A1) + (nY * B1) + (nZ * C1) \qquad (6.12)$$

$$n112p_{\min} = (nX * A2) + (nY * B2) + (nZ * C2) \qquad (6.13)$$

nX, nY and nZ in formulas-12 and 13 define the number of X, number of Y and number of Z values. Meaning of X, Y and Z are described in Table 6.9. PSAP minimum and maximum values are found with the additional filtration rates which are the author calculations in Table 6.14. Its meanings are A1 for 0-19K, B1 for 19K-100K and C1 for 100K-140K in the minimum values; while the rate of maximum values is A2 for 0-19K, B2 for 19K-100K and C2 for 100K-140K.

X, Y, Z total range will be in 3 sigma after these calculations. If the C1 rate is decreased to 0.5 and C2 rate is decreased to 0.8 rates; numbers of PSAPs are fitted to the Government formal numbers in nearly 4 sigma. It can enable to understand what the government rate is of the current status and what the results of function FS8 are.

On the other hand, this population enables to see the current eCall PSAPs in the calculation for Overall System Cost (75 in Figure 6.2, Result-3). It enables also the architecture selections with result-3. Nevertheless; the target in the architecture selection and cost model calculation is mainly to see the Result-1 and Result-2 in Figure 6.2 to compare the possible architecture variants of the Figures in Chapter-7. This will be enabled by the Call Event-Based eCall PSAP Calculation.

-Call Event-Based eCall PSAP Calculation (FS9)-

The annual eCall events of the accidents after the eCall equipped vehicle regulations in 2018 will be calculated with the rate; based on accident rates in the country. Accident rates in PSAPs will be more than the number of accidents in the calculation year because the manual eCall units can be used both wrong and right applications. As an example of a wrong application for the manual eCall unit, input button on the manual eCall units can be pushed when there is no accident. But there is no status like that for the automatic eCall units in the vehicles.

The number of accidents [1] with fatality or injury is explained for the countries in the Case Studies in Chapter-7. With this number and the wrong calls from Manual eCall Units of the eCall equipped vehicles in 2018, the rate of estimated eCall events can have a range of minimum and maximum values. The conversion from eCall events to PSAP-workers are explained in the function 'FS1'. With the conversion which is explained in FS1, the numbers of workers are rated for new eCall events. These eCall workers can be;

- In a new eCall PSAP
- In the current 112 PSAP
- In rescue services

These possibilities are explained in the Part 5.2 and Part 5.3 in details. Integrate the eCall services to the 112 PSAP (or rescue station) can enable the possibility of free of charge status from the building costs or office costs. In all cases; workstation costs and costs in infrastructure (Figure 6.6) about the personnel working and events will exist. The new eCall PSAPs are created in the study with the architectures in the Architecture-Figures of Chapter-7. The calculated workers with the function FS1 are processed with the Table 6.10 in function FS7 which means the relation between a number of PSAP workers and PSAP Types enables to see the minimum and maximum values of the number of PSAPs. It is required for new eCall structures. Like the population-based PSAP-calculation, this calculation also needs the filtration rate after the result of Table 6.10 correlation. Its processes can be summarized with the eCall process flow (PFE):

- PFE-1: Number of Call events is saved with the minimum rate and maximum rate for 2018 year assumption. (see Case Studies in Chapter-7)
- PFE-2: The country call events are converted to the number of workers with the function FS1 includes the Table 6.7.
- PFE-3: Calculated numbers of workers are rated within Table 6.10 and the function FS7 is applied to the number of workers.
- PFE-4: Function FS7 application enables to see the number of PSAPs (number of PSAP workers → number of PSAPs) with its sizes (X,Y or Z). Normally, PFE-4

needs to be the result. But, these rates give the wrong results. Because the countries in every '0-19000 population' or '19000-100000 population' or '100000-140000 population' does not include the PSAP. Some small populations are combined with the big size populations such as villages can be combined to the cities. So the PSAP numbers can be decreased. These results are filtrated with the filtration rates A3, B3 and C3.

- PFE-5: A3, B3 and C3 are the filtration rates of the number of PSAPs in call-event base calculations.
- PFE-6: A3, B3, C3 rates enable the correct call event-base calculation to be in 3 sigma interval of the 6 sigma rules. These rates are calculated by the author with the info support of six sigma rules, and it is measured in Matlab/Simulink environment. Then it is applied to the study.
- PFE-7: A3, B3, C3 rates are defined in Table 6.15.
- PFE-8: After the function of FS7, numbers of PSAP-X type are multiplied with A3; numbers of PSAP-Y type are multiplied with B3; the numbers of PSAP-Z Type is multiplied with C3.The results are given as function-FS9 with the minimum and maximum values, which mean the future eCall PSAP rates minimum and maximum values between 3 sigma and 4 sigma in the 6 sigma rules.

Table 6.15 Filtration Rates vs. Values for Event-Based Calculations

A3	B3	C3
0.0786	0.5108	0.41

Taking everything into consideration, new PSAPs are calculated with the additional eCall events in the formulas-6.14, 6.15.

$$np_{\max} = \left(\frac{A * npw_{\max}}{X1_{\max}}\right) + \left(\frac{B * npw_{\max}}{Y1_{\max}}\right) + \left(\frac{C * npw_{\max}}{Z1_{\max}}\right) \qquad (6.14)$$

$$np_{\min} = \left(\frac{A * npw_{\min}}{X1_{\min}}\right) + \left(\frac{B * npw_{\min}}{Y1_{\min}}\right) + \left(\frac{C * npw_{\min}}{Z1_{\min}}\right) \qquad (6.15)$$

Formula-6.14 and 6.15 give the results for a number of PSAPs as minimum and maximum values (np in f8). These formulas are the event-base calculations for new-PSAPs which are defined in Figure 6.6 as item-62 and 62.1. "npw" is the number of PSAP workers based on eCall events after eCall-equipped vehicle regulations. A, B and C are the number of PSAP types in Table 6.13 (also in Table 7.2, Table 7.4, Table 7.10, Table 7.14 and Table 7.18 for case-study countries) when X1, Y1 and Z1 are the minimum and maximum emergency service workers per station via its sizes. ‘npw’ minimum and maximum values are produced by the calculations of Table 6.7 and FS1.

The filtration rates in Table 6.15 are calculated with Table 6.13. Table 6.13 includes the whole country Population with the X, Y, Z Types of PSAPs. X rate in the total PSAP is rated as A3, Y Rate in the total PSAP is B3 and Z Rate in the total PSAP is C3.

As a conclusion, PFE-4 values are multiplied with A3, B3 and C3; and then the final results for eCall PSAPs are enabled.

Conclusively, the number of PSAPs (FS7) is used in the calculations of Infrastructure system cost (43) which is the part of total infrastructure system (47). Its definition is:

- FS7 is multiplied with ‘45.1’
- The depreciation period with discount rate is applied to this result
- The function FS10 is added.
- Finally, the result which is described totally as item-45 is summed into the total Infrastructure System Cost (71).

-Emergency Services Training Costs (FS10)-

Emergency services training costs are calculated with the multiplication of the terms below:

- Number of Emergency Service Workers (FS1 in FS9 for eCall services, FS1 in FS8 for current emergency services)
- Unit costs of training units

Unit training costs are rated with EU travel expenses [178], and its units are;

- Meal
- Accommodation
- Travel
- Education

In EU travel expenses, the total amount of allowance for the expenses is not exceeded 400 € without education price and this is also applied in the study.

6.6 Simulation Environment of Cost Modelling

Next generation architectures of EENA-Models are defined in the Case studies in Chapter-7 thanks to Chapter-5 and Chapter-6. Its cost model study is explained in this section. These studies are analyzed in Matlab/Simulink environment with the data properties below:

- Rural, Urban, and Motorway are analyzed with all types of injuries; an accident with fatality, an accident with severe injury, an accident with slight injury.
- The year-based data is loaded for 2018 due to being starting time of EU-2015/758 eCall equipped vehicle regulation.
- Processed-Country road infrastructure is introduced as Best-Perform, wors-perform in European Union or EU Accending; so the road characteristics are analyzed with this information.
- Good and passenger transportations are analyzed for Processed-Country [176] in vehicle mileages of passenger cars, light-duty and heavy-duty. Its application in the simulation analyzes especially passenger car characteristics.
- The processed-country population is the real country data provided by World Bank [184].
- Fuel Types are analyzed for both diesel and gasoline. Its application in the simulation includes especially diesel rates.
- Fuel Volumes are introduced as net volume and gross volume. Net volume is loaded in the simulation.
- Emission standards are introduced between EU-1 and EU-6. In the simulation, EU-6 is processed.
- Equipment rates are loaded by author calculation with the data support ACEA report [133].
- Fuel Consumption constants are analyzed with Lam Formula [128-129] with default values.
- Driver reaction shift forward is analyzed between 0 second and 3 seconds with optimal data at 0.5 second.
- Emergency services discount rates are loaded for 20 years with 3% discount rate.
- Ecall equipment unit prices are entered between 100 € and 150 € with 8 years depreciation period and 3 % discount rate.
- Emergency service workers’ working hour is between 8 and 12 hour.
- Emergency service expenses are loaded with the data of EU-expenses [178].

- Unit cost rates such as accident cost unit rate, time cost unit rate, tax unit rates are defined with the real membership prices by road vehicle report and membership state reports [123-125, 134-135].
- Time duration of Emergency call events are analyzed between 1.5 minute and 2 minutes [125].
- Unit cost of emergency calls are described between 0.3 € and 0.6 € for correct calls and 0.1 € and 0.2 € for wrong (ghost) calls with EU-Roaming Data [177].

Simulation in Matlab/Simulink environment is studied in three subgroups:

- Status in Urban Way with Slight Injuries in the Country.
- Status in Rural Way with Severe Injuries in the Country.
- Status in Motorway with Fatalities in the Country

These road and injury/fatality rates are analyzed in the cost model study which includes the simulations for the case-study countries. All 'road'-'injury/fatality' rates are compared for the road types as this road type is like 100 %-exist in this country. The case study results (Figure 7.3, Figure 7.5, Figure 7.8, Figure 7.10, and Figure 7.11) for the countries are analyzed with this logic. In Discussion part (Chapter-8), the costs and BCRs are processed with road rates which enable to see the country real prices and country real BCRs. For Example, Case Study-1 (Finland) BCR for urban way with slight injury is between 6 and 12 (all roads like urban way and all injuries like slight injury), BCR for rural way with severe injury is between 13 and 23 (all roads like rural way and all injuries like severe injury), and also BCR for motorway with fatality is between 1378 and 2434 (all roads like motorway and all injuries like fatality). When the country-specific real BCR results in Table 8.1, road rates of Finland (76 % rural way, 18 % motorway and 6 % urban way) is multiplied with these BCR rates and the results are produced between 269 and 476 in Discussions, Chapter-8 (all road types in the country with all injury types). This calculation is not required when the BCR comparisons, cost comparisons are analyzed in simulation results in Case Study section (Chapter-7) because of the objective which is the aim of optimal architecture selection.

The three main results in Figure 6.2 which is the simulation results of cost model study for the optimal architectures are created with the logical approaches below:

- Annuity Present Value (APV) (74) is enabled by the difference of 'Savings After the regulations' and 'Savings Before the regulations'. Savings are life savings, time savings, decreasing the accident severity enabled by the increase of intelligent vehicle system structure (an increase of the equipment rates; the function of 43, 44 via savings). It means the net benefit.

- Benefit to Cost Ratio (BCR) (47) is enabled by Total System Cost divided by Annuity Present Value. Total System Cost defines the eCall system costs which are the sum of; (i) Infrastructure System Cost, (ii) eCall Component Cost in the vehicles, (iii) cost increase of the vehicle system due to new technology is set into the vehicle; being intelligent vehicle (function of 43,44 via costs).
- Overall Emergency Costs (in Figure 6.2) (75) is enabled by the sum of total system cost including next-generation vehicle accident cases and current system costs which is for public issues without vehicle cases.

In the Figures of Chapter-7 such as Figure 7.1, Figure 7.4, Figure 7.6, Figure 7.7 and Figure 7.9, the next generation architectures which are put into the data. They are sequenced with respect to their benefits and low-cost status.The results are shown in Figures of Chapter-7 such as Figure 7.3, Figure 7.5, Figure 7.8, Figure 7.10, and Figure 7.11.

CHAPTER 7

COUNTRY BASED CASE STUDIES

The eCall system current status and its next generation structure are defined in Chapter-3 as the generic systems. Then, its current architectures which are applied in the countries, next-generation improvements, next-generation status of current applied architectures are explained in Chapter-5. Moreover, number of possible next generation architectures are also emphasized in the same part. Then, optimal architecture selection citeria via cost modelling are analyzed in details with respect to intelligent vehicle and road safety system, infrastructre and components. In this chapter, the country-specific studies enable to understand which architectures can be the optimal solution for the current EENA,Models after eCall equipped vehicle regulations in 2018. The case-studies of EENA,Models are focus on Finland as EENA,Model-5; Turkey as EENA,Model-4; United Kingdom as EENA,Model-2; Germany and Italy as EENA, Model-1.

The ‘model-type’ definitions of architectures in the Figures such as Figure 7.1, Figure 7.4, Figure 7.6, Figure 7.7 and Figure 7.9 are read with the logical approach as it is shown in Figure 7.0.

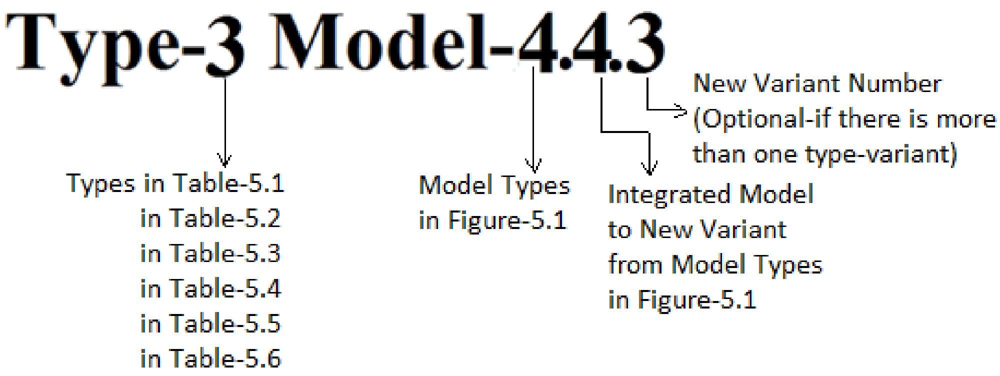

Figure 7.0 'Model-Type' Reading of Figures in Case Study Architectures

In Figure 7.0, example type number '3' is the eCall receiving type in Tables such as Table 5.1, Table 5.2, Table 5.3, Table 5.4, Table 5.5 and Table 5.6. The first number of Model which is 4 in the example is the model type of Figure 5.1. Then, the second number in Model reading which is 4 in the example is the integrated model type into the architecture after eCall equipped vehicle regulation. The last number of Model reading which is also 4 in the example is an optimal number which is used if there exists more than one variant of the same model types.

7.1 Case-Study-1: Finland

- Section-1: The Optimal Architectures-

According to the infrastructure and service properties which are mentioned in Table 5.1 to Table 5.6 and explained in the Rescue and Dispatch processes, 38 Architecture types (in Table 5.1 to Table 5.6) can be varied. After the variant filtration via fitting with Finland infrastructure, there exist 18 architecture variants. The optimal eight architectures and two interconnected PSAP architecture types are summarized for Finland which has the "ERO Independent PSAP" model. The optimum cases in the architectures are analyzed and decided via cost models in the simulation of Matlab/Simulink environment. The eight architectures and two interconnected PSAP architectures mentioned above are schematized in Figure 7.1.

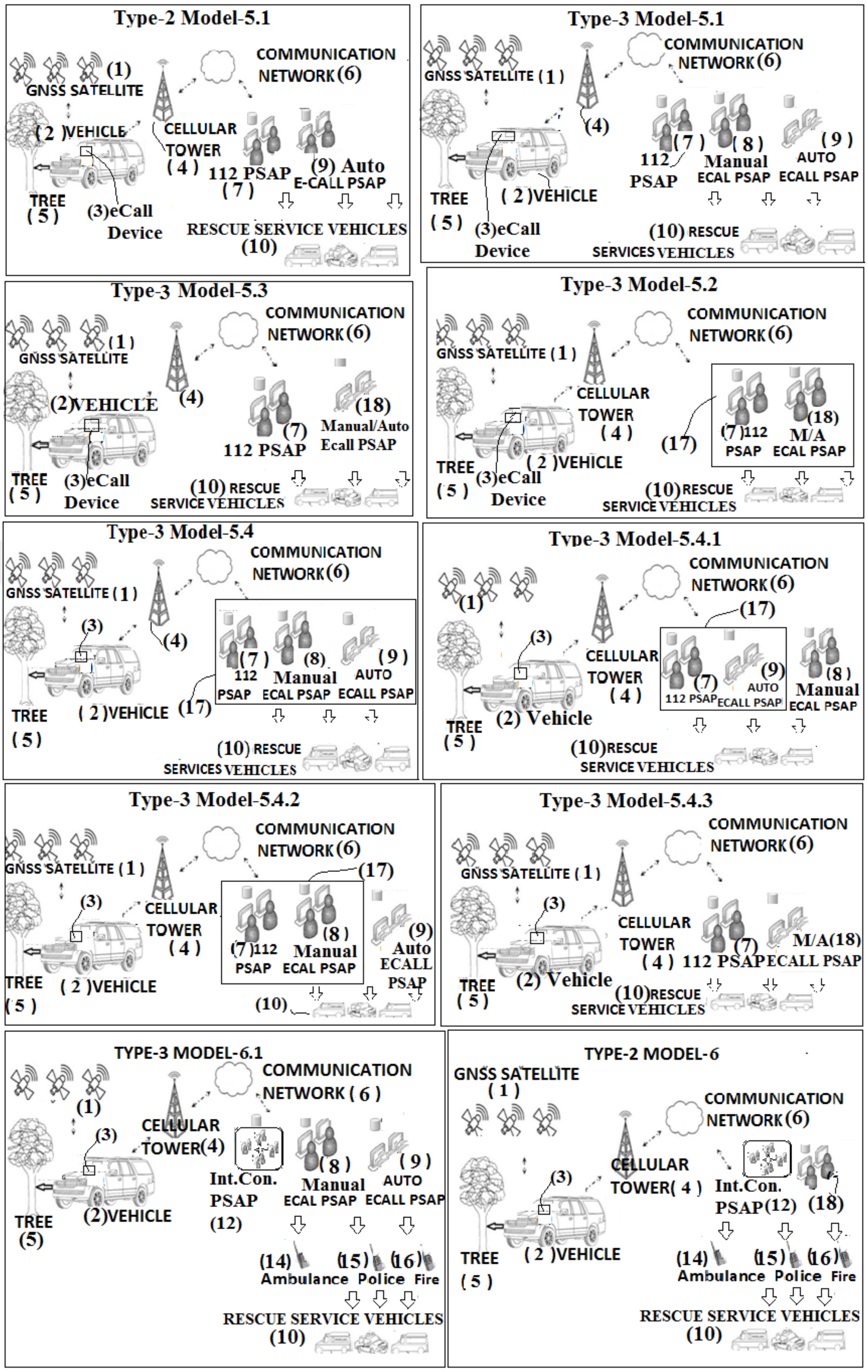

Figure 7.1 Possible New ECall System Architectures for “ERO Independent PSAP” Model

In Figure 7.1, there are two PSAPs which are most appropriate 112 PSAP (7) and Auto eCall PSAP (9) in Type-2 Model-5.1. Automatic eCall PSAP (9) is working for only accident issues of the vehicles which have automatic eCall unit when 112 PSAP is working on all public issues. In type-3 model-5.1, Manuel (8) and Auto eCall (9) PSAPs are used with 112 PSAPs (7). In this structure, manual and auto eCall PSAPs are related to in-vehicle eCall events when 112 PSAPs are working about other public situations. Type-3 Model-5.3 has 112 PSAP (7), and Manuel/Auto eCall (18) PSAPs. Unit-18 means the Manual and Auto eCall PSAP is one unit. It can be integrated unit or only one of eCall PSAP. Next, type-3 model-5.2 has 112 PSAP (7) with Manual/Auto eCall PSAP (18) in the integrated control room/building (17). Moreover, Type-3 model-5.4 includes 112 PSAP (7), Manual eCall PSAP (8) and Auto eCall PSAP (9) in an integrated control room/building (17). In this type, Manual and Auto eCall PSAPs can be described also as Manual/Auto eCall PSAP (8 and 9 in an integrated structure can be defined as 18). Next, Type-3 Model-5.4.1 explains the integrated room/building (17) includes 112 PSAP (7) and Auto eCall PSAP (9). In this type, Manual eCall PSAP (8) is outside of the control room building (17). When type-3 Model-5.4.2 includes 112 PSAP (7) and Manuel eCall PSAP (8) inside the control room/building, its Auto ECall PSAP (9) is outside of the control room/building. In addition to them, Type-3 Model-5.4.3 describes the structure including 112 PSAP (7) and Manual/Auto ECall PSAP (18) without any rescue service station for dispatch process. These 8 architectures take the emergency calls and make the dispatches to the rescue services (10) without any rescue stations. By the way, type-3 model 6.1 and Type-2 model-6 has the interconnected PSAP (12) with eCall units. Interconnected 112 PSAP is the answering point which is connected to other 112 PSAPs in the same region in the same country. When type-3 model-6.1 has two eCall PSAPs as Manual eCall PSAP (8) and Auto eCall PSAP (9), Type-2 Model-6 has integrated unit as Manual/Auto eCall PSAP (18). The interconnected PSAP structures are especially emphasized in this paper because of the fact that the studies which are made before this article include the interconnected structures for next generation of Finland architectures. The old studies' details are defined in Part 1.1 in Literature Review of Section 3. In this study, it can be seen whether the interconnected PSAPs are the optimal architectures for Finland or not.

- <u>Section-2: Intelligent Vehicle and Road Safety Finland Specific Data-</u>

-Transportation Rates-(Function F2 in Part 6.4)-

ECall architecture is investigated for next generation of "ERO Independent PSAP" model which is Finland-architecture has the transportation rates yearly as shown in Figure 7.2.

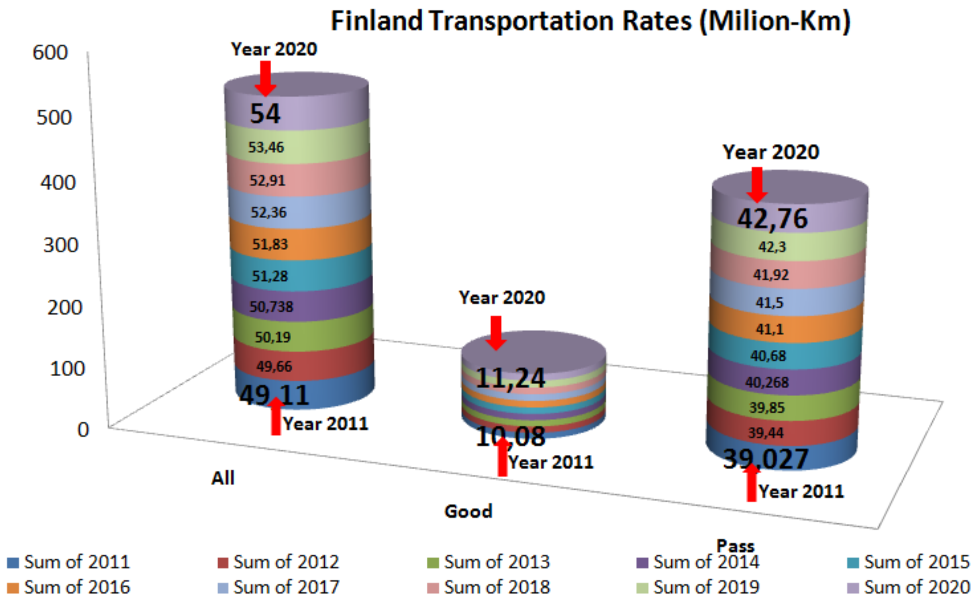

Figure 7.2 Finland Transportation Rates (Author Calculation with the data support of ACEA Report-2004)

In Figure 7.2, good and passenger transportation are summarized. When the passenger transportation is about 41.92 Million Km in 2018, good transportation is about 10.8 Million Km. These rates increase totally up to 54 Million Km until 2020 in Finland which has an ERO-Independent PSAP Model at the current status.

-Accident Cost Unit Rates-('02' Parameter; ACur in Part 6.4)

According to Finnish Transport Agency 2014 report [1], the unit cost of an accident with the fatality is 2.4 M€ when the unit cost of an accident with severe injury is 309 K€. On the other hand, unit cost with slight injury is about 3200 €. The fatality cost unit rate is ten times greater than injury accident cost unit rate. That shows; if the life saving is enabled by the smart vehicle and road safety improvements that means the net benefit side in Figure 6.2, it enables not only social impact but also economic impact.

-Time Cost Unit Rates-('01' Parameter; TCur in Part 6.4)

The time cost unit rates for Finland is calculated by the author with the data support of Planco Consulting Gmbh report [190] summarized as; (i) 10 €/h for passenger cars, 30 €/h for Light-Duty and Trucks,60 €/h for Busses.

-Operating Cost Unit Rate-(Output-O4 Parameter in Part 6.4)

Fixed operating cost unit rate is expressed with vehicle type [176] that; its passenger car rate is 9.16 €/100 km, its truck rate is 14.19 €/100 km, its semi-trailer rate is 24.37 €/100km and its Bus rate is 45.90 €/100 km.

-Fuel Consumption Rates-('04' Parameter; FCur in Part 6.4)

The annual fuel consumption in 2018 in Finland [179] is calculated by the author with the data support of trading economic agency is 3712 Million Litres. When 2123 Million liters are the diesel fuel consumptions on the road, 1595 Million liters is gasoline consumption. Fuel rate in the simulation is calculated by fuel-consumption to see the correct result of vehicle operating cost which defines the total fuel price.

-Road Rates-(in Function F7 of Part 6.4)

In this article, Finland road rate [180] is processed in the simulation with 6 percent urban-way of all roads, 76 percent rural-way of total roads and 18 percent motorways. With these rates, total vehicle mileages are analyzed separately in all roads. As an example; when the severe injury in rural roads in Finland is investigated, the total vehicle mileage in Finland (total mileage is 52.9 Billion km; passenger transportation 41.9 Billion km and good transportation 11 Billion km in 2018) is rated via rural roads and the mileage value is multiplied with rural road rate, 76.

-Number of Accidents-(in Function F7 of Part 6.4)

Finland is a best-performing country in EU; so the accident rates for Finland are changing between 1 and 5 per 1 billion vehicle kilometers. (see Table 6.5)

- Section-3: Infrastructure Rates Finland Specific Data-

-Country Population Rates-(in Function FS8 of Part 6.5)

Finland Population which is 5.4 Million [181] is separated into the population groups via city and counties. The separation rates of total population are summarized in Table 7.1. Country populations are grouped according to population rates.

Table 7.1 Grouped County-Population Rates of Countries

Population Rate	Exist Rate in Finland	Population Rate	Exist Rate in Finland	Population Rate	Exist Rate in Finland
0-19K	22	140K-240K	2	500K-750K	0
19K-100K	35	240K-340K	3	750K-1M	0
100K-140K	4	340K-500K	1	1M-1.2M	1

All grouped-populations in Table 7.1 are converted to the 0-19K, 19K-100K and 100K-140K populations. This conversion is created via PSAP Types in NENA standards to see how many PSAPs are needed. After this process, formal PSAP numbers are noted from EENA data [119,135] and they (formal numbers and calculated numbers) are correlated with each other. This enables to see the correct PSC rates to create (in Table 6.14) and the rates in Table 6.15 are also calculated thanks to this process. Finland population which is rated in Table 7.1 is finally converted to three types of populations; X, Y, Z which are also PSAP types population rates in Table 7.2.

Table 7.2 Grouped County-Population Rates via 3 Basic Populations

Population Rate	Total Rate in Finland
0-19K	26
19K-100K	48
100K-140K	16

This is to say, in Table 7.2, it is understood how many PSAPs exist in Finland. But these rates give the wrong results. Because the countries in every ‘0-19000 population’ or ‘19000-100000 population’ or ‘100000-140000 population’ does not include the PSAP in Finland. Some small populations are combined with the big size populations such as villages can be combined to the cities. So the PSAP numbers can be decreased. These results are filtrated with the filtration rates A1, B1, C1 and A2, B2, C2 in Part 6.5 in Table 6.14.

-Number of Accident Rates-(in Function FS1, FS9 of Part 6.5)

A Number of road-accidents in Finland in Road Safety 2014-annual report [1] is 6400 which will be the rate of eCall events (nce) via eCall-equipped vehicle after the regulations. On the other hand, "nce" for all public issues for overall 112-PSAPs in Finland is 3550K when 1112K events are false calls [175].

- Section-4: Simulation Results Architecture Optimization Finland Specific Data-

In Figure 7.3, next-generation architectures which are explained in Figure 7.1 are put into the data. They are sequenced with respect to their benefits and low-cost status.

LOW BENEFIT → HIGH BENEFIT

RATIOS & DATA	TYPE-3 MODEL-6.1	TYPE-3 MODEL-5.1	TYPE-2 MODEL-6	TYPE-3 MODEL-5.4.2	TYPE-3 MODEL-5.4.1	TYPE-3 MODEL-5.4.3	Type-3 Model-5.4	Type-3 Model-5.3	Type-2 Model-5.1	Type-3 Model-5.2
BCR--Urban Way With Sligth Injury	3,462	3,62	4,3	4,31	4,31	4,311	5,17	5,248	5,249	6,12
BCR--Rural Double Way With SevereInjury	13,05	13,9	16,231	16,236	16,236	16,236	19,505	19,769	19,77	23,04
BCR--Motor Way With Fatality Injury	1378	1469	1714	1715	1715	1715	2060	2088,6	2088,7	2434
APV(Benefit-Sum)Urban Way With Sligth Injury	24066T€	24671T€	25984T€	25987T€	25987T€	25987T€	27303T€	27390T€	27391T€	28306T€
APV(Benefit-Sum) Rural Double Way With SevereInjury	11769 T€	11830T€	11961T€	111962T€	11962T€	11962T€	112093T€	12102T€	12102T€	12193T€
APV(Benefit-Sum) Motor Way With Fatality Injury	13457 M€	13458M€	13459M€	13460 M€	13460 M€	13460 M€	13461M€	13461M€	13461M€	13462M€
Overall Emergency Costs (Ecalls+Other Public Issues+All 112 Calls)All Roads,All Injury	153 M€	152 M€	151 M€	151 M€	151 M€	151 M€	150 M€	150 M€	150 M€	149 M€

BENEFIT INCREASES IN ALL LINEs

MINIMUM EMERGENCY SYSTEM COSTS DECREASE

Figure 7.3 Simulation Results of Next Generation "ERO-Independent PSAP" Model Types, Finland

In Figure 7.3, BCR and APV values for all three scenarios has the best value in Type-3 Model-5.2. Then, type-2 model-5.1 is the second option of next-generation architecture for Finland. The Third alternative can be Type-3 Model-5.3. Benefit to Cost Ratio is changing between 3.4 and 6.12 for slight injuries (all roads like urban way and all injuries like slight injury) when it is between 13 and 23 for severe injuries (all roads like rural way and all injuries like severe injury). In fatalities, unit costs are so high described in this section "accident cost unit rates". It shows the effect in the results, so BCR is changing between 1378 and 2434 (all roads like a motorway and all injuries like fatality). When APV is changing between 24 M€ and 28 M€ in urban-way with slight injuries, it is between 11 M€ and 12 M€ in rural double way with severe injuries.

Finally, APV for motorway with fatality rates are changing between 13457 M€ and 13460 M€. Nevertheless, overall emergency service costs can have at least minimum values between 153 M€ and 149 M€ as it is shown in Figure 7.3.

The architectures which include only Auto eCall PSAP (9) and it does not have any Manual eCall PSAP (8) such as Type-2 Model-5.1 can be applied to the countries if the related country releases the additional regulation after the EU regulation 2015/758 [40] is started to be applied in 2018. It means manual eCall devices in the vehicles will be regulated and they need to turn to automatic eCall device in a short time period. If the Manual eCall devices in the vehicles are permitted to be used in many years by government, the second architecture option, Type-2 Model-5.1 needs to be applied as Type-3 Model-5.3 which is also third architecture option. If Manual eCall devices are used in many years in the related country, and the Manuel eCall PSAPs in the country does not exist; there can be the problematic status for not only 112 PSAP but also Auto eCall PSAP. As a conclusion, infrastructure can be re-organized after the first-fixed architecture in 2018 if the applicable standard of the related country is not defined exactly.

As a conclusion, Finland can choose the next-generation architecture with the sequence: (i) The Best Option: Type-3 Model-5.2, (ii) Second-Alternative: Type-2 Model-5.1 (Associated with the application standard of related country; see above paragraph), (iii) Third Option: Type-3 Model-5.3, (iv) Fourth Option: Type-3 Model-5.4, (v) 5th – 7th Options: they are nearly equal to each other's about the gain and cost; so they can be prefer whether Type-3 Model-5.4.3 or Type-3 Model-5.4.1 or Type-3 Model-5.4.2, (vi) 8th Option: Type-2 Model-6; (vii) 9th Option: Type-3 Model-5.1 and (viii) worst-option: Type-3 Model-6.1.

7.2 Case Study-2: Turkey

- Section-1: The Optimal Architectures-

According to the infrastructure properties which are explained in Part 5.3.4 of Chapter-5, 38 Architecture types (Table 5.4) can be varied. After the variant filtration via fitting with Turkey infrastructure, there exist 16 architecture variants. The optimal six architectures are summarized for Turkey which has the "Data Gathering by stage PSAP1 and resource dispatching by stage PSAP2 in an integrated control room" model in Figure 7.4.

In addition to the explained units in Figure 3.1,Figure 3.2 and Figure 5.1, unexplained units will be described. Unit-19 is a rescue service station which makes the dispatches to the all rescue service vehicles. If unit-19 is in usage, there is no need to use the units 14, 15 and 16 to make dispatches. On the other hand, the difference between unit-13 and unit-19 is that; unit-13 emphasizes emergency related rescue service which can be a police station and/or ambulance station and/or fire station when unit-19 is one service which is used for dispatches of all rescues.

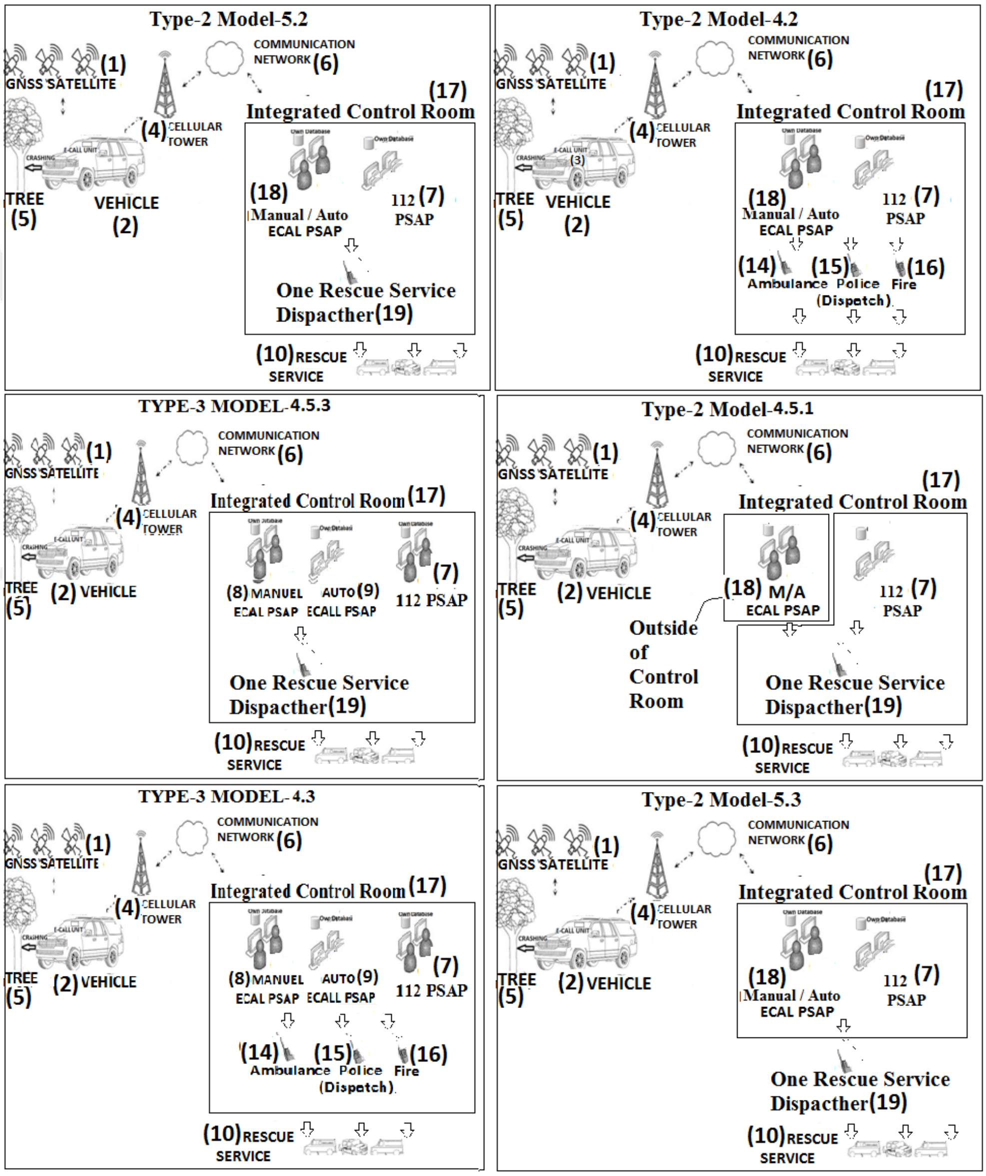

Figure 7.4 Possible New ECall System Architectures for EENA, Model-4; Turkey Case

In Figure 7.4, there are integrated eCall PSAP (18) and 112 PSAP (7) with one rescue service (19) in Type-2 Model-5.2. Integrated eCall PSAP (18) is working for accident issues of the vehicles which have automatic eCall unit or manual eCall unit when 112 PSAP is working for the other public issues. In addition, one rescue service (19) makes dispatches of all EROs. In type-2 model-4.2, Manuel/Auto eCall PSAP (18) and 112 PSAP (7) are the PSAPs and ambulance unit (14), police unit (15) and fire unit (16) which are used as different units for the dispatch processes. Next, type-3 model 4.5.3 has an integrated control room/building concept (17) including Manual eCall PSAP (8), Auto eCall PSAP (9), 112 PSAP (7) differently and one rescue service unit (19) exists for all rescues. On the other hand, type-3 model-4.3 is the same structure with type-3 model-4.5.3; but the only difference is having all rescue service units as the different units (14 and 15 and 16) in type-3 model-4.3. Moreover, 112 PSAP (7) and one rescue service unit (19) are in the integrated control room/building in Type-2 model-4.5.1 when the M/A eCall PSAP (18) is outside of control room/building at the same architecture. Finally, there exist integrated control room building (17) including Manual/Auto eCall PSAP (18) and 112 PSAP (7) when one rescue service (19) is outside of control room in Type-2 Model-5.3.

- <u>Section-2: Intelligent Vehicle and Road Safety Turkey Specific Data-</u>

-Transportation Rates-(Function F2 in Part 6.4)

ECall architecture is investigated for next generation of “Data Gathering by stage PSAP1 and resource dispatching by stage PSAP2 in an integrated control room” model which is Turkey-architecture has the transportation rates yearly as two types. These are:

- Goods Transportation
- Passenger Transportation

When the passenger transportation is about 380 Million Km in 2018, good transportation is about 275 Million Km. These rates are calculated by the author with the data support of 2013 Turkey Statistics report [185-186].

-Accident Cost Unit Rates-(‘02’ Parameter; ACur in Part 6.4)

According to EU Transport Agency 2014 report [1], the unit cost of an accident with a fatality is 1.516 M€ when the unit cost of an accident with severe injury is 0.2 M€. On the other hand, unit cost with slight injury is about 22 K€. Fatality cost unit rate is eight times greater than injury accident cost unit rate. That shows; if the life saving is enabled by the smart vehicle and road safety improvements that means the net benefit side of Figure 6.2, it enables not only social impact but also economic impact.

-Time Cost Unit Rates-('01' Parameter; TCur in Part 6.4)

The time cost unit rates for Turkey is calculated by the author with the data support of Planco Consulting Gmbh report [190] summarized as; (i) 12 €/h for passenger cars, 24 €/h for Light Duty and Trucks,74 €/h for Busses.

-Operating Cost Unit Rates-(Output-O4 Parameter in Part 6.4)

Fixed operating cost unit rate is expressed with vehicle type [176] that; its passenger car rate is 9.16 €/100 km, the truck rate is 14.19 €/100 km, semi-trailer rate is 24.37 €/100km and bus rate is 45.90 €/100 km.

-Fuel Consumption Rates-('04' Parameter; FCur in Part 6.4)

The annual fuel consumption in 2018 in Turkey is calculated by the author with the data support of MIT Energy and Environment Report [182] is 35 Billion Litres. When 12 Billion liters are the diesel fuel consumptions on the road, 23 Billion liters is gasoline consumption. Fuel rate in the simulation is calculated by fuel-consumption to see the correct result of vehicle operating cost which defines the total fuel price.

-Road Rates-(in Function F7 of Part 6.4)

In this article, Turkey road rate [183] is processed in the simulation with 47 percent urban-way of all roads, 49 percent rural-way of total roads and 4 percent motorways. With these rates, total vehicle mileages are analyzed separately in all roads. As an example; when the severe injury in rural roads in Turkey is investigated, the total vehicle mileage in Turkey (total mileage is 655 Million km; passenger transportation 380 Million km and good transportation 275 Million km in 2018) is rated via rural roads and the mileage value is multiplied with rural road rate, 49.

-Number of Accidents-(in Function F7 of Part 6.4)

Turkey is a Non-EU country; so the accident rates for Turkey are changing between 10 and 24 per 1 billion vehicle kilometers. (see Table 6.5)

- Section-3: Infrastructure Rates Turkey Specific Data-

-Country Population Rates-(in Function FS8 of Part 6.5)

Turkey Population which is 75.932 Million [184] is separated into the population groups via city and counties. The separation rates of total population are summarized in Table 7.3. Country populations are grouped according to population rates below.

Table 7.3 Grouped County-Population Rates of Countries (Author Calculation with the data support of World Bank Data [184])

Population Rate	Exist Rate in Turkey	Population Rate	Exist Rate in Turkey	Population Rate	Exist Rate in Turkey
0-19K	363	140K-240K	63	500K-750K	16
19K-100K	391	240K-340K	39	750K-1M	7
100K-140K	60	340K-500K	36	1M-1.2M	0

All grouped-populations in Table 7.3 are converted to the 0-19K, 19K-100K and 100K-140K populations. This conversion is created via PSAP Types in NENA standards to see how many PSAPs are needed. After this process, formal PSAP numbers are noted from EENA-data [119,135] and they are correlated with each others. This enables to see the correct PSC rates to create (in Table 6.14) and the rates in Table 6.15 are also calculated thanks to this process. Turkey population which is rated in Table 7.3 is finally converted to three types of populations; X, Y, Z which are also PSAP types population rates in Table 7.4.

Table 7.4 Grouped County-Population Rates via 3 Basic Populations

Population Rate	Total Rate in Finland
0-19K	449
19K-100K	630
100K-140K	317

This is to say, in Table 7.4, it is understood how many PSAPs exist in Turkey. But these rates give the wrong results. Because the countries in every ‘0-19000 population’ or ‘19000-100000 population’ or ‘100000-140000 population’ does not include the PSAP in Turkey. Some small populations are combined with the big size populations such as villages can be combined to the cities. So the PSAP numbers can be decreased. These results are filtrated with the filtration rates A1, B1, C1 and A2, B2, C2 in Part 6.5 in Table 6.14.

-Number of Accident Rates-(in Function FS1, FS9 of Part 6.5)

A Number of road-accidents in Turkey in Road Safety 2014-annual report [185,186] is 161K which will be the rate of eCall events (nce) via eCall-equipped vehicle after the regulations. On the other hand, “nce” for all public issues for overall 112-PSAPs in Turkey is 1M when 79M events are false calls which is calculated with the data support of Turkey and European annexes [187, 188].

- Section-4: Simulation Results Architecture Optimization Turkey Specific Data-

In Figure 7.5, next-generation architectures which are explained in Figure 7.4 are put into the data. They are sequenced with respect to their benefits and low-cost status.

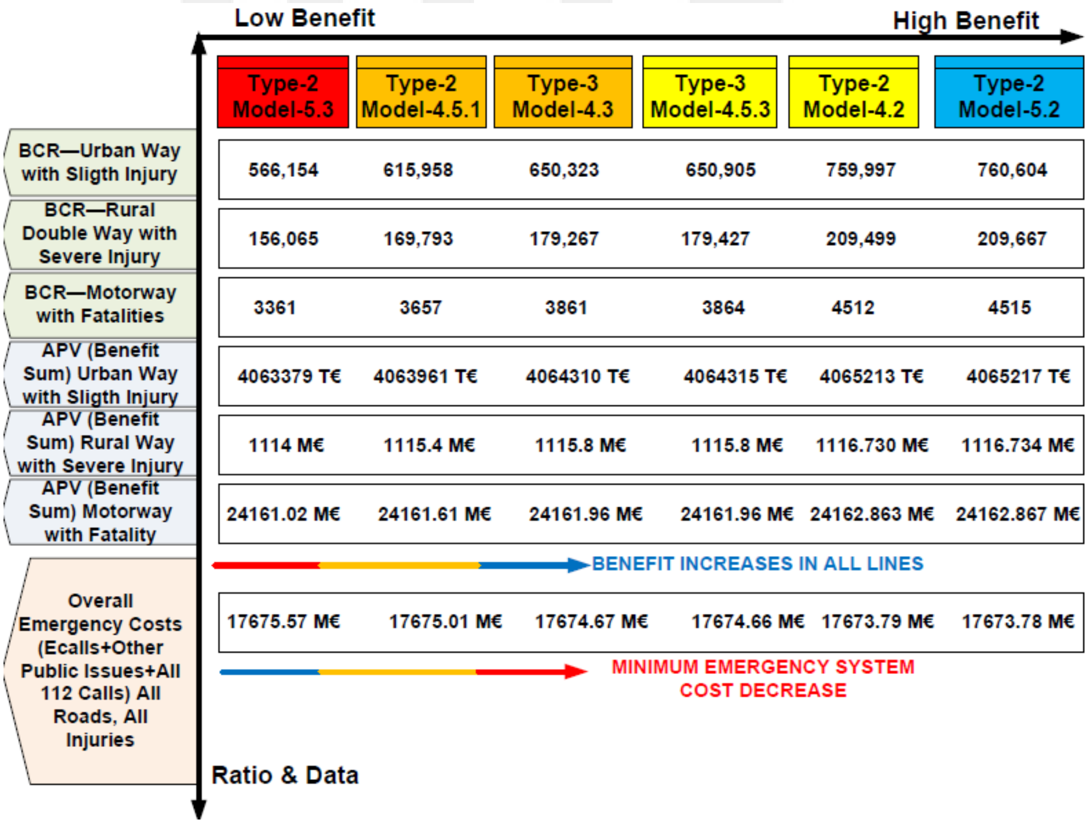

Figure 7.5 Simulation Results of Next Generation EENA,Model-4, Turkey Case Study

In Figure 7.5, BCR and APV values for all three scenarios has the best value in Type-2 Model-5.2. Then, type-2 model-4.2 is the second option of next-generation architecture for Turkey. The Third alternative can be Type-3 Model-4.5.3. Benefit to Cost Ratio is

changing between 566 and 760 for slight injuries (all roads like urban way and all injuries like slight injury) when it is between 156 and 209 for severe injuries (all roads like rural way and all injuries like a severe injury). In fatalities, unit costs are so high described in this part as “accident severity section”. It shows the effect in the results, so BCR is changing between 3361 and 4515 (all roads like a motorway and all injuries like fatality). When APV is changing between 4063379 T€ and 4065217 T€ in urban-way with slight injuries, it is between 1114 M€ and 1116 M€ in the rural double way with severe injuries. Finally, APV for motorway with fatality rates are changing between 24161 M€ and 24162 M€. Nevertheless, overall emergency service costs can have at least minimum values between 17675 M€ and 17673 M€ as it is shown in Figure 7.5.
As a conclusion, Turkey can choose the next-generation architecture with the sequence: (i) The Best Option: Type-2 Model-5.2, (ii) Second-Alternative: Type-2 Model-4.2, (iii) Third Option: Type-3 Model-4.5.3, (iv) Fourth Option: Type-3 Model-4.3, (v) 5th Option: Type-2 Model-4.5.1, (vi) 6th Option: Type-2 Model-5.3;

7.3 Case Study-3: UK

- <u>Section-1: The Optimal Architectures-</u>

As it is emphasized in Table 5.2 in Part 5.3.2, 10 of 38 variant in the architectures with the new regulations can be applied to the “Filtering Stage-1 PSAP and Resource dispatch stage-2 PSAP” model. This model is described in Model-2 of Figure 5.1 & Figure 5.8 and its next generation in Figure 5.9. Its current structure includes 112 PSAP and related rescue service(s). The next generation possibilities are analyzed with the available 10 architectures and 6 of them are summarized in Figure 7.6 below. The details of a selection of these architectures result in Chapter-6 “Cost Model Study”, Chapte-8 “Discussion” and Chapter-9 “Conclusion”. Moreover, its modeling conditions are analyzed in Part 6.6.

In Figure 7.6, it is obvious that the architectures include the integrated control room/building concept. In fact, there can be also the other types of possible-architectures which are also defined in Figure 7.7 without integrated control room concept. But, their cost model results show that Figure 7.7 concepts’ possibility is lower than the Figure 7.6 concepts; so, the Figure 7.6 concepts are investigated in deep dive in this study.

In addition to the explained units in Figure 3.1, Figure 3.2 and Figure 5.1, the unit which has been defined in case study-2 is remembered. Unit-19 is a rescue service station which makes the dispatches to the all rescue service vehicles. If unit-19 is in usage, there is no need to use the units 14, 15 and 16 to make dispatches. On the other hand, the difference between unit-13 and unit-19 is that; unit-13 emphasizes emergency related rescue service which can be a police station and/or ambulance station and/or fire station when unit-19 is one service which is used for dispatches of all rescues.

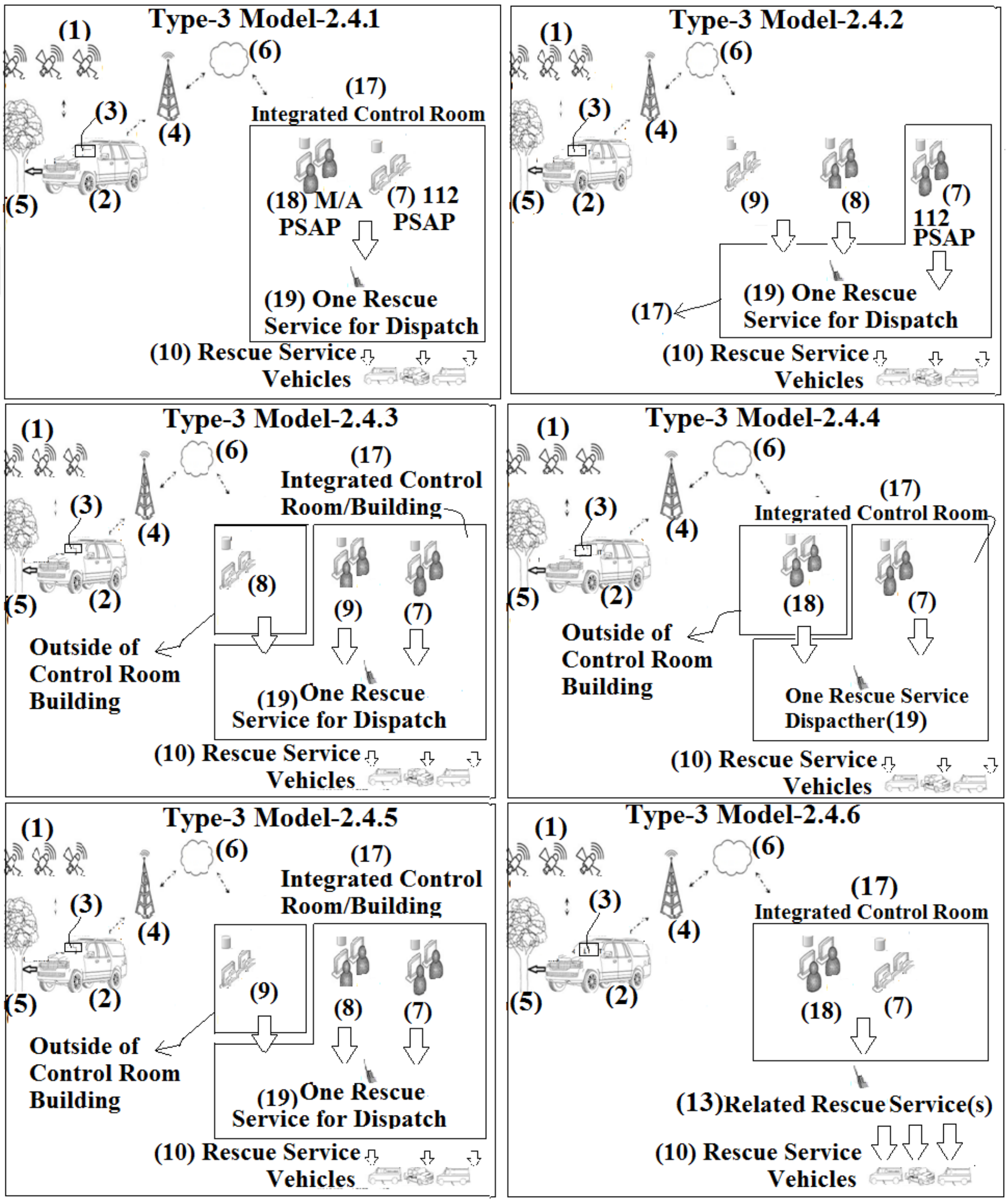

Figure 7.6 Possible New eCall System Architectures for EENA, Model-2; U.K. Case

In Figure 7.6, Type-3 Model-2.4.1 includes Manual/Automatic Ecall PSAP (18), 112 PSAP (7) and one rescue service for dispatch (19). Next, Type-3 Model-2.4.2 defines the same system but the eCall PSAPs (8, 9) are out of control room/building. Moreover, Type-3 Model-2.4.3 has all PSAPs differently (7, 8 and 9) with one rescue service dispatcher (19). When 112 PSAP (7) and Auto eCall PSAP (9) is in the same control room/building (17) with dispatcher unit (19), manual eCall PSAP (8) is outside of control room/building. When both Type-3 Model-2.4.4 and Type-3 Model-2.4.5 have 112 PSAP (7) in the integrated control room (17) with one rescue service for dispatch (19), their eCall PSAP structures are different. Type-3 Model-2.4.4 has Manual/Automatic eCall PSAP (18) at different control room/building while Type-3 Model-2.4.5 has Manual eCall PSAP (8) inside of integrated control room/building (17). Automatic eCall PSAP (9) is outside of integrated control room/building (17) in Type-3 Model-2.4.5. Finally, Type-3 Model-2.4.6 sets up the 112 PSAP (7) and Manual/Auto eCall PSAP (18) inside of the integrated control room. Its rescue service unit (13) for dispatch is outside of control room/building.

According to Part 4.2.1 and Table 4.4, EENA,Model-2 in Figure 5.7 and Figure 5.8 at the current status has the Rescue Person-Type as Low-Trained. All architectures of Figure 7.6 advise using the Middle-Level Trained rescue-persons with their properties. The trained-person properties are improved by the Countries with the EENA standards [135].

As it is emphasized at the beginning of this section, Type-3 Model-2.2.1 and Type-3 Model-2.2.2 in Figure 7.7 are the options out of 6 architectures in 10 possible architectures for the next generation of current Model-2 in EENA. In Type-3 Model-2.2.1, 112 PSAP (7) is one unit when the Manual/Auto eCall PSAP (18) is another unit. The rescue services can be different for all rescue services (14, 15, and 16) or it can be used as one dispatcher unit (13). The difference of Type-3 Model-2.2.2 is having different eCall Units (8, 9). The rescue service situations whether being only item-13 or being the stations 14, 15 and 16 is not the main case for these architectures; because their infrastructure status has low benefit when it is compared with Figure 7.6 architectures.

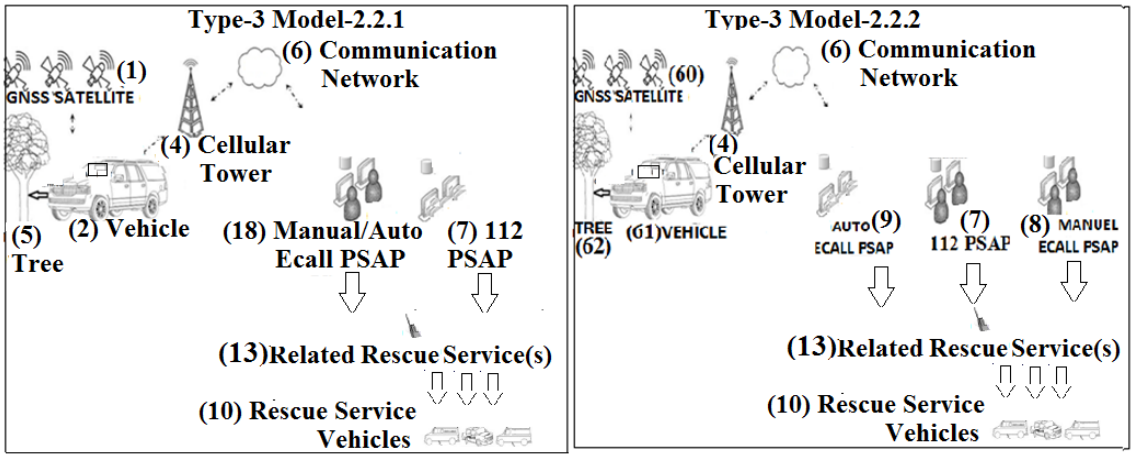

Figure 7.7 Next-Generation Emergency Call Possible Architectures for EENA Model-2 (United Kingdom); Other Possibilities

- Section-2: Intelligent Vehicle and Road Safety U.K. Specific Data-

-Transportation Rates- (Function F2 in Part 6.4)

The annual transportation rates in MKm for the United Kingdom are summarized below in Table 7.5 with the author calculation including the supporter data of European Transport Report [169].

Table 7.5 Yearly Transportation Rates

Year	Good Transportation (MKm)	Passenger Transportation (MKm)
2011	79.390	415.099
2012	80.409	419.464
2013	81.429	423.770
2014	82.449	428.214
2015	83.468	432.659
2016	84.488	437.104
2017	85.507	441.410
2018	86.527	445.854
2019	87.546	450.299
2020	88.566	454.688

In Table 7.5, good and passenger transportations are summarized in United Kingdom (UK). When the passenger transportation is about 445 MKm in 2018, good transportation is about 86,5 MKm.

-Accident Cost Unit Rates-(‘02’ Parameter; ACur in Part 6.4)

IRTAD report [1] shows the accident cost unit rate in the accidents with fatalities is 1.9 M€ while the accident with severe injury is about 219 K€. In addition, cost unit rate of an accident with slight injury is 2 K€. It means the decrease of fatalities enables the huge amount of savings which defines also the saving difference between item-46 and item-45 in Figure 6.2.

-Time Cost Unit Rates-('01' Parameter; TCur in Part 6.4)

The time cost unit rates for United Kingdom [121] is summarized as below:

Table 7.6 Time Cost Unit Rates of United Kingdom

Vehicle Type / Time Cost Unit Rates	United Kingdom Rate (€/h)
Passenger Cars	13
Light Duty / Trucks	14
Buses	82

-Operating Cost Unit Rates-(Output-O4 Parameter in Part 6.4)

Fixed operating cost unit rate is expressed with vehicle type [176] as it is shown in Table 7.7.

Table 7.7 Fixed Operating Cost Unit Rates of United Kingdom

Vehicle Type	Fixed Operating Cost (€/100 km)
Passenger Car	9.16
Truck	14.19
Semi Trailer	24.37
Bus	45.90

-Fuel Consumption Rates-('04' Parameter; FCur in Part 6.4)

The country is the United Kingdom and its annual fuel consumption is summarized in Table 7.8. The data of Table 7.8 is the author calculation with the data support of MIT laboratory for energy and environment [182].

Table 7.8 The Yearly Fuel Consumption Rates of United Kingdom

Consumption Year	Gasoline Fuel Consumption (10^9 Litres)	Diesel Fuel Consumption (10^9 Litres)
2010	24.3	8.3
2011	24.2	8.5
2012	24.1	8.7
2013	24	8.9
2014	23.9	9.1
2015	23.9	9.4
2016	23.8	9.6
2017	23.7	9.8
2018	23.6	10
2019	23.6	10.2
2020	23.5	10.5

-Road Rates-(in Function F7 of Part 6.4)

Road types are described in function ‘F5’. and its rates for United Kingdom [121] are summarized as below:

- Urban way rate in U.K. is 47 %
- Rural way rate in U.K. is 35 %
- Motorway rate in U.K. is 18 %

-Number of Accidents-(in Function F7 of Part 6.4)

United Kingdom is a best-perform country in EU; so the accident rates for the United Kingdom are changing between 2 and 5 per 1 billion vehicle kilometers. (see Table 6.5)

- <u>Section-3: Infrastructure Rates U.K. Specific Data-</u>

-Country Population Rates-(in Function FS8 of Part 6.5)

U.K. Population which is 64.510 Million [184] is separated into the population groups via city and counties. The separation rates of the total population are summarized in Table 7.9. Country populations are grouped according to population rates.

Table 7.9 United Kingdom Population-Separations with the Code-Letters

Population Size	Existence in United Kingdom (Number of Population Size Rate)	Code-Letter	Population Size	Existence in United Kingdom (Number of This Rate)	Code-Letter
0-19000	11	A	1.6M-1.8M	0	L
19K-100K	363	B	1.8M-2M	0	M
100K-140K	27	C	2M-2.5M	0	N
140K-240K	25	D	2.5M-3M	0	O
240K-340K	6	E	3M-3.5M	0	P
340K-500K	3	F	3.5M-4M	0	R
500K-750K	2	G	4M-4.5M	0	S
750K-1M	27	H	4.5M-5M	0	T
1M-1.2M	1	I	5M-6M	0	U
1.2M-1.4M	9	J	6M-7M	0	V
1.4M-1.6M	5	K	7M-8M	1	Y

This is to say, the United Kingdom includes the population groups via sizes in 2nd columns and 5th columns. If the process flow in Part 6.5 is remembered; in PF-5, it means the code letters (3^{rd} column and 6^{th} column) are associated with the 2^{nd} column and 5^{th} column in Table 7.9 which are sequenced in the United Kingdom population.

Up to now, Unit Population rates with the code letters are defined and United Kingdom Populations are re-written by Code Letters how many population groups the United Kingdom has. At the moment, as it is described in PF-5 (in FS8), the United Kingdom population via A, B and C can be defined in Table 7.10. In Table 7.10, United Kingdom population is evaluated with A, B, and C code letters. All other code-letters (in Table 7.9) are also converted to A, B and C code letters.

Table 7.10 United Kingdom Whole Population with the Code-Letters of A,B,C

PSAP Type	Population Size	Existence of A,B,C Populations in the whole United Kingdom Population (64.5 Million)	Code-Letter
X	0-19000	87	A
Y	19K-100K	565	B
Z	100K-140K	454	C

This is to say, in Table 7.10, it is understood how many PSAPs exist in U.K.. But these rates give the wrong results. Because the countries in every '0-19000 population' or '19000-100000 population' or '100000-140000 population' does not include the PSAP in U.K.. Some small populations are combined with the big size populations such as villages can be combined to the cities. So the PSAP numbers can be decreased. These results are filtrated with the filtration rates A1, B1, C1 and A2, B2, C2 in Part 6.5 in Table 6.14.

-Number of Accident Rates- (in Function FS1, FS9 of Part 6.5)

Number of road-accidents in U.K. in Road Safety 2014-annual report [1] is 151346 which will be the rate of eCall events (nce) via eCall-equipped vehicle after the regulations. On the other hand, "nce" for all public issues for overall 112-PSAPs in U.K is 31M for Stage-1 PSAP when this number is % 60 of 31M call events [189].

- <u>Section-4: Simulation Results Architecture Optimization U.K. Specific Data-</u>

In Figure 7.8, Benefit to Cost Ratio (49, Result-1 in Figure 6.2), Annuity Present Value (48, Net Benefit in Figure 6.2) and Overall System Cost (50, Total Emergency Costs in Figure 6.2) are summarized as the simulation results for the next generation architectures of the United Kingdom to choose the optimal architecture.

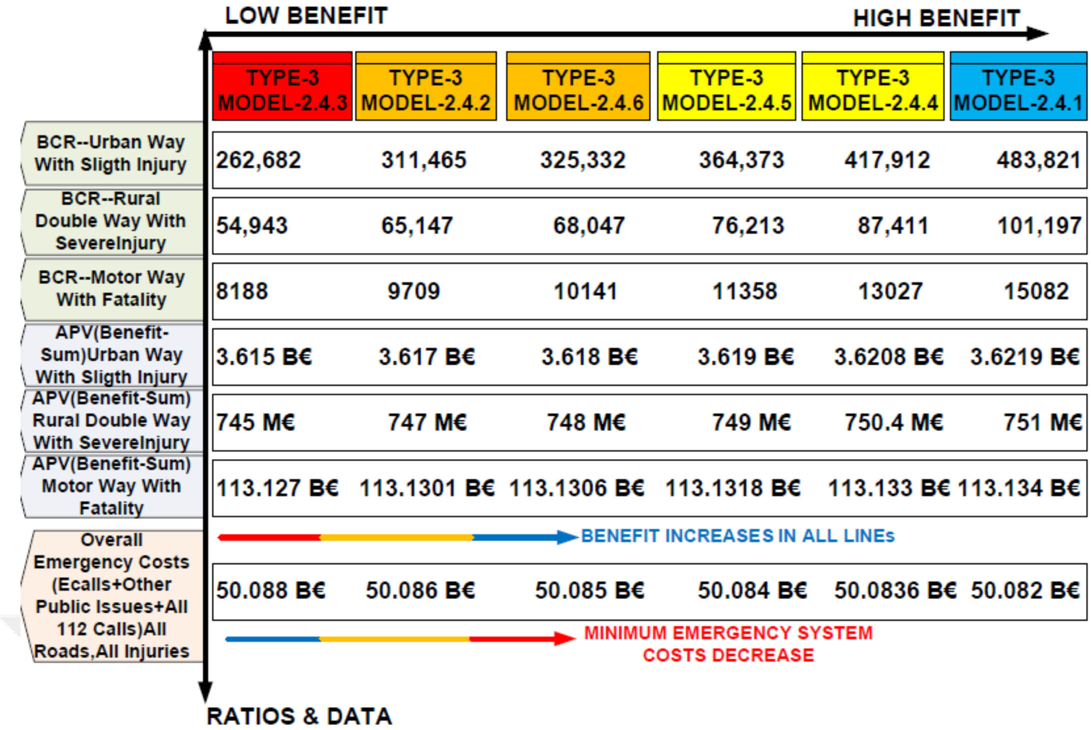

Figure 7.8 Simulation Results of Next Generation EENA,Model-2 Types, U.K. Case Study

In Figure 7.8, Benefit to Cost Ratio in Urban Way for the accident of slight injuries (all roads like urban way and all injuries like slight injury) is between 262 and 483. Next, Benefit to Cost Ratio in Rural Double Way or Rural Single Way for the accident of severe injuries (all roads like rural way and all injuries like a severe injury) is between 54 and 100. Then, Benefit to Cost Ratio in Motorway for the accident of fatalities (all roads like a motorway and all injuries like fatality) is between 8K and 15K.

In Figure 7.8, Annuity present value in Urban Way for the accident of slight injuries (all roads like urban way and all injuries like slight injury) is about 3.6 B€. Next, Net benefit in Rural Double Way or Rural Single Way for the accident of severe injuries (all roads like rural way and all injuries like a severe injury) is about 745-750 M€. Then, Benefit to Cost Ratio in Motorway for the accident of fatalities (all roads like motorway and all injuries like fatality) is about 113 B€.

In Figure 7.8, Total emergency service costs including eCall equipped vehicle emergency calls, public emergency calls, infrastructure costs, call event costs, office costs in 2018 is annually estimated as about 50 B€.

In Figure 7.8, when the architectures are compared with the terms which are explained above, the results from the optimal alternative to the worst case are below:

- The best option is Type-3 Model-2.4.1
- Second alternative can be Type-3 Model-2.4.4
- Third optimal case is Type-3 Model-2.4.5
- Fourth case is Type-3 Model-2.4.6
- Fifth Case is Type-3 Model-2.4.2
- Worst Case of these six architectures is Type-3 Model-2.4.3

7.4 Case Study-4: Italy

- Section-1: The Optimal Architectures-

"Emergency Calls EROs Handling PSAP" model was explained in Figure 5.2 and Figure 5.3 with Model-1 in which its infrastructure does not include any PSAP service externally due to the fact that one of Rescue Service is working as PSAP. According to Model-1 infrastructure property, 38 Architecture types in Table 5.1 can be filtered. After the variant filtration, 12 architectures can be applied to Italy which has the "Emergency Calls EROs Handling PSAP" model. The optimal 6 of 12 architectures via cost models are analyzed and decided with the simulation, which is shown in Figure 7.9. The details of the simulation study are explained in Chapter-6.

In Figure 7.9, Type-2 Model-5.2 has an integrated control room concept (17) includes manual/auto eCall PSAP (20) and 112 PSAP (7) with one rescue dispatch unit (18) when Type-2 Model-4.2 includes the same PSAP types (7, 20) with all rescue units (14, 15, 16). Next, Type-2 Model-5.6 includes only two PSAPs as Manual/Auto eCall PSAP (20) and 112 PSAP (7) in which both giving responses to emergency calls and making dispatches to the rescue service vehicles (11). Type-2 Model-5.1 has the 112 PSAP for call-response and one rescue service unit (18) for the dispatch process in integrated control room/building (17) when Manual/Auto Ecall PSAP (20) is outside of the Control Room (19). Type-2 Model-4.1 has the same structure with Type-2 Model-5.1, but the only the difference is that includes the all rescue services (14, 15, 16) in the integrated control room (17). Finally, Type-2 Model-3 has Manual/Auto eCall PSAP (20) and 112 PSAP (7) for call response and making dispatches with rescue stations (14, 15 and 16).

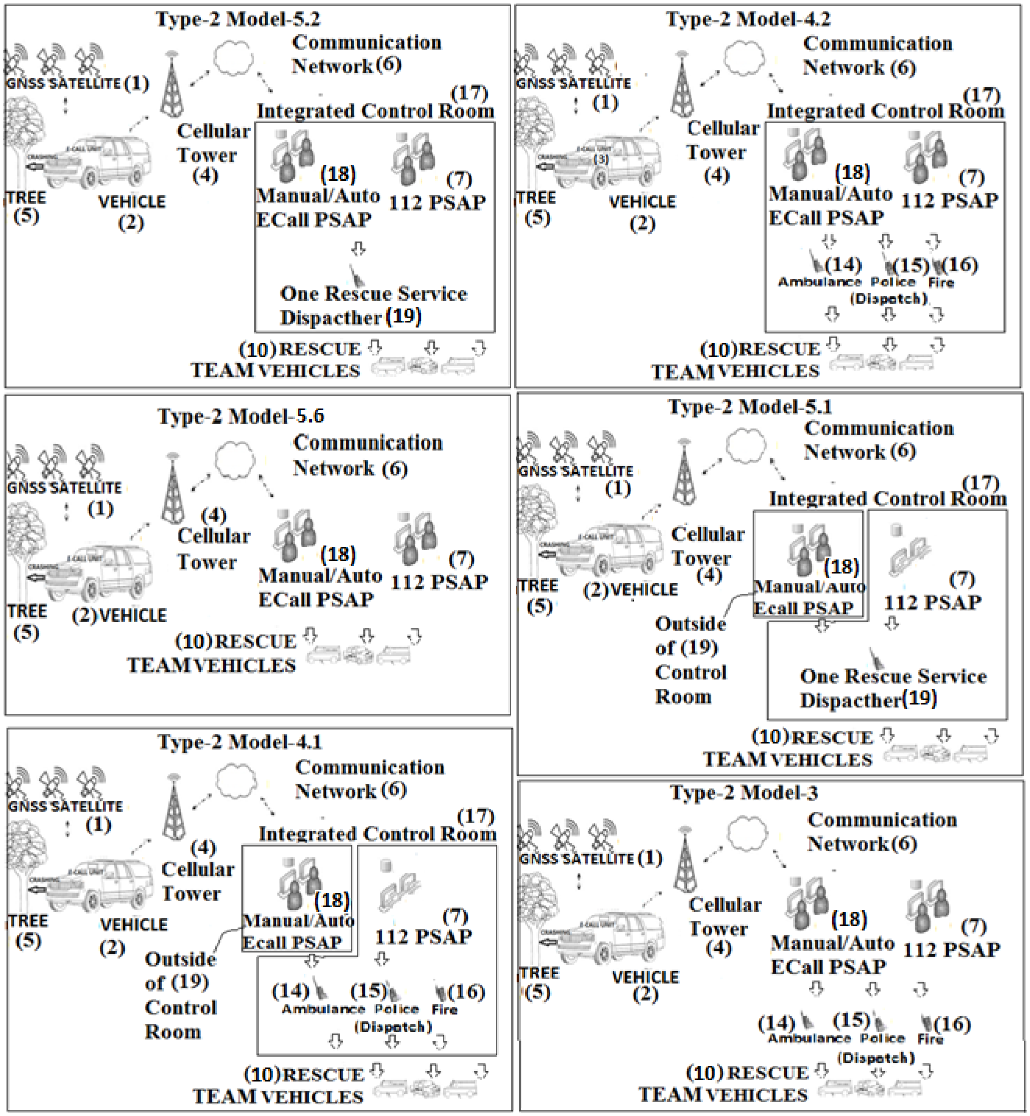

Figure 7.9 Possible New ECall System Architectures for EENA, Model-1, Italy Case

- <u>Section-2: Intelligent Vehicle and Road Safety Italy Specific Data-</u>

-Transportation Rates-(Function F2 in Part 6.4)

Country transportation data which is for Italy in this paper is calculated by author with the data support of world transport report [169]. When passenger transportation is 478 MKm in 2018, good transportation is about 98 MKm and vice versa.

-Accident Cost Unit Rates-('02' Parameter; ACur in Part 6.4)

According to IRTAD Annual Report, unit cost of fatality is around 1503000 € when severe injury unit cost is 197000 € in Italy. Next, slight injury unit cost is about 17000 € in Italy. It shows the cost difference between fatality unit cost and injury unit costs.

-Time Cost Unit Rates-('01' Parameter; TCur in Part 6.4)

The time cost unit rates for Italy is calculated by the author with the data support of Planco Consulting Gmbh report [190] summarized below:

Table 7.11 Time Cost Unit Rates of Italy

Vehicle Type / Time Cost Unit Rates	Italy Rate (€/h)
Passenger Cars	12
Light Duty / Trucks	24
Buses	74

-Operating Cost Unit Rates-(Output-O4 Parameter in Part 6.4)

Fixed operating cost unit rate is expressed with vehicle type [176] as it is shown in Table 7.12.

Table 7.12 Fixed Operating Cost Unit Rates of EU, Italy

Vehicle Type	Fixed Operating Cost (€/100 km)
Passenger Car	9.16
Truck	14.19
Semi Trailer	24.37
Bus	45.90

-Fuel Consumption Rates-('04' Parameter; FCur in Part 6.4)

The country is Italy and its annual fuel consumption is summarized as 29.416 10^9Liters in Italy in 2018 and it was 30.408 10^9 liters in 2015. It is the author calculation with the supporter data of MIT laboratory for energy and environment [182].

-Road Rates-(in Function F7 of Part 6.4)

Road types are described in function 'F5' and its rates for Italy which has the "Emergency Calls EROs handling" model are 487,700 km includes 6700 km of express ways is rated in the simulation via being rural, urban and motorway.

-Number of Accidents-(in Function F7 of Part 6.4)

Italy is a best-perform country in EU; so the accident rates for Italy are changing between 2 and 5 per 1 billion vehicle kilometers. (see Table 6.5)

- <u>Section-3: Infrastructure Rates Italy Specific Data-</u>

-Country Population Rates-(in Function FS8 of Part 6.5)

Italy Population which is 61.336 Million [184] is separated into the population groups via city and counties. The separation rates of the total population are summarized in Table 7.13. Country populations are grouped according to population rates.

Table 7.13 Italy Population-Separations with the Code-Letters

Population Size	Existence in Italy (Number of Population Size Rate)	Code-Letter	Population Size	Existence in Italy (Number of This Rate)	Code-Letter
0-19000	65	A	1.6M-1.8M	1	L
19K-100K	480	B	1.8M-2M	0	M
100K-140K	21	C	2M-2.5M	1	N
140K-240K	46	D	2.5M-3M	1	O
240K-340K	25	E	3M-3.5M	0	P
340K-500K	23	F	3.5M-4M	0	R
500K-750K	16	G	4M-4.5M	0	S
750K-1M	8	H	4.5M-5M	0	T
1M-1.2M	2	I	5M-6M	0	U
1.2M-1.4M	1	J	6M-7M	0	V
1.4M-1.6M	2	K	7M-8M	0	Y

This is to say, Italy includes the population groups via sizes in 2nd columns and 5th columns. If the process flow in Part 6.5 is remembered; in PF-5, it means the code letters (3rd column and 6th column) are associated with the 2nd column and 5th column in Table 7.13 which are sequenced in the Italy population.

Up to now, Unit Population rates with the code letters are defined and Italy Populations are re-written by Code Letters how many population groups Italy has. At the moment, as it is described in PF-5, the Italy population via A, B and C can be defined in Table 7.14. In Table 7.14, Italy population is evaluated with A, B, and C code letters. All other code-letters (in Table 7.13) are also converted to A, B and C code letters.

Table 7.14 United Kingdom Whole Population with the Code-Letters of A,B,C

PSAP Type	Population Size	Existence of A,B,C Populations in the whole Italy Population (61.3 Million)	Code-Letter
X	0-19000	145	A
Y	19K-100K	711	B
Z	100K-140K	290	C

This is to say, in Table 7.14, it is understood how many PSAPs exist in Italy. But these rates give the wrong results. Because the countries in every ‘0-19000 population’ or ‘19000-100000 population’ or ‘100000-140000 population’ does not include the PSAP in Italy. Some small populations are combined with the big size populations such as villages can be combined to the cities. So the PSAP numbers can be decreased. These results are filtrated with the filtration rates A1, B1, C1 and A2, B2, C2 in Part 6.5 in Table 6.14.

-Number of Accident Rates-(in Function FS1, FS9 of Part 6.5)

A Number of road-accidents in Italy in Road Safety 2014-annual report [1] is 186726 which will be the rate of eCall events (nce) via eCall-equipped vehicle after the regulations. On the other hand, “nce” for all public issues for overall 112-PSAPs in Italy is 11.9M for PSAPs when 9.6M is false call events [187].

- Section-4: Simulation Results Architecture Optimization Italy Specific Data-

In Figure 7.10, Benefit to Cost Ratio (49, Result-1 in Figure 6.2), Annuity Present Value (48, Net Benefit in Figure 6.2) and Overall System Cost (50, Total Emergency Costs in Figure 6.2) are summarized as the simulation results for the next generation architectures of Italy to choose the optimal architecture.

In Figure 7.10, BCR and APV values for three subgroups have the best value in Type-2 Model-5.2. Type-2 Model-4.2 is the second option of next-generation architecture for “Emergency calls EROs handling” in Italy. Next, Type-2 Model-6 can be the third alternative to apply. Benefit to Cost Ratio is changing between 180 and 241 for slight injuries in urban ways (all roads like urban way and all injuries like a slight injury) when it is between 63 and 84 for severe injuries in rural ways (all roads like rural way and all injuries like a severe injury). Moreover, benefit to cost ratio is high as between 3721 and 4977 for fatalities in motorways (all roads like a motorway and all injuries like fatality) which shows the importance of saving life and the difference of accident cost unit rates described in Part 3.2.

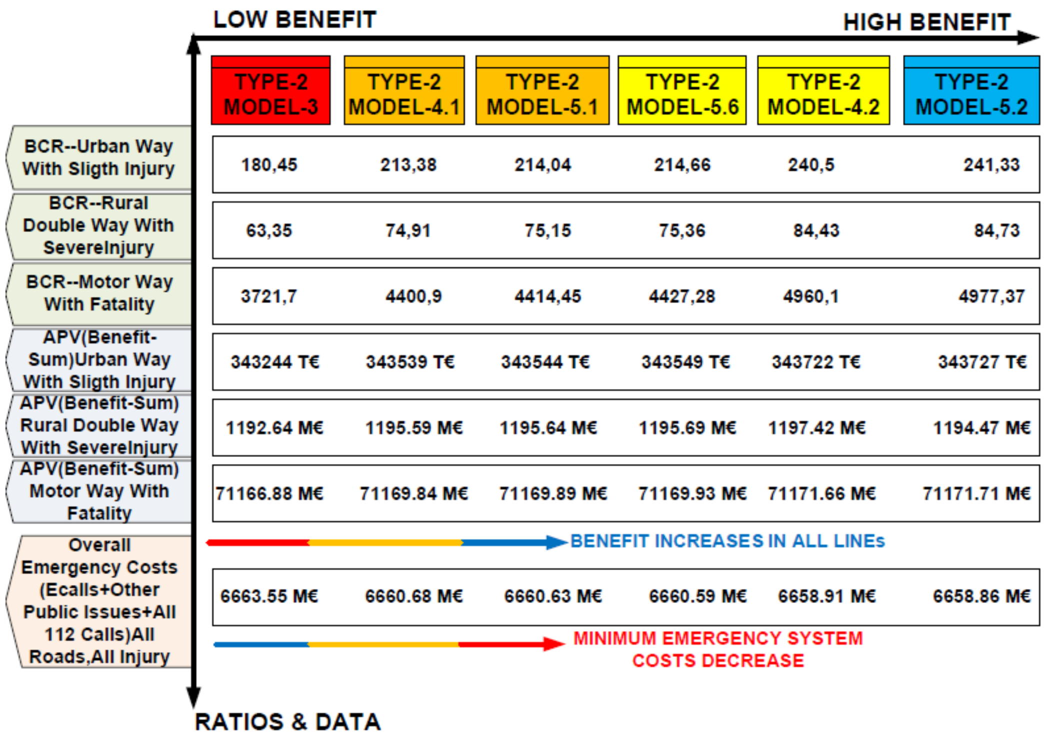

Figure 7.10 Simulation Results of Next Generation EENA,Model-1 Types, Italy Case Study

When APV is changing between 343244 T€ and 343727 T€ in urban ways, it is between 1192.64 M€ and 1194.47 M€ in rural ways. Next, it is between 71166 M€ and 71171 M€ in motorways. On the other hand, overall emergency costs are between 6663.55 M€ and 6658.86 M€ in all hands. (T€=10^3 €, M€= 10^6 €)

As a conclusion, Italy can choose the next generation architecture with the sequence below:

(i)The best option: Type-2 Model-5.2; (ii) 2nd Option: Type-2 Model-4.2; (iii) 3rd Option: Type-2 Model-6; (iv) 4th Option: Type-2 Model-5.1; (v) 5th Option: Type-2 Model-4.1 (vi) Worst- option of these optimal six architectures: Type-2 Model-3.

7.5 Case Study-5: Germany

- Section-1: The Optimal Architectures-

Possible next-generation architectures of “Emergency Calls EROs Handling PSAP” model was explained in Case Study-4 with Figure 7.9. The same architecture variants are applicable also to Germany Case. The only difference of Germany İnfrastructure from Italy İnfrastructure is the usage of Rescue station as 112 PSAP. When the police station (15) is used as 112 PSAP (7) in Italy, fire station (16) is used as 112 PSAP in Germany and vice versa.

- Section-2: Intelligent Vehicle and Road Safety Germany Specific Data-

-Transportation Rates- (Function F2 in Part 6.4)

Vehicle Mileage is calculated by carrying good or passenger in transportation. Country transportation data which is for Germany in this paper is calculated by the author with the data support of world transport report [169]. When passenger transportation is 577 MKm in 2018, good transportation is about 63.95 MKm and vice versa.

-Accident Cost Unit Rates-('02' Parameter; ACur in Part 6.4)

According to IRTAD Annual Report [1], the unit cost of a fatality is around 1161892 € when severe injury unit cost is 116151 € in Germany. Next, slight injury unit cost is about 12323 € in Germany. It shows the cost difference between fatality unit cost and injury unit costs.

-Time Cost Unit Rates-('01' Parameter; TCur in Part 6.4)

The time cost unit rates for Germany is calculated by the author with the data support of Planco Consulting Gmbh report [190] summarized below:

Table 7.15 Time Cost Unit Rates of Germany

Vehicle Type / Time Cost Unit Rates	Germany Rate (€/h)
Passenger Cars	11
Light Duty / Trucks	32
Buses	66

-Operating Cost Unit Rates-(Output-O4 Parameter in Part 6.4)

Fixed operating cost unit rate is expressed with vehicle type [176] as it is shown in Table 7.16.

Table 7.16 Fixed Operating Cost Unit Rates of EU, Germany

Vehicle Type	Fixed Operating Cost (€/100 km)
Passenger Car	9.16
Truck	14.19
Semi Trailer	24.37
Bus	45.90

-Fuel Consumption Rates-('04' Parameter; FCur in Part 6.4)

The country is Germany and its annual fuel consumption is summarized as 44.504 10^9Liters in Germany in 2018 and it was 44.840 10^9 liters in 2015. It is the author calculation with the supporter data of MIT laboratory for energy and environment report [182].

-Road Rates-(in Function F7 of Part 6.4)

In this case, the roads of Germany which have the "Emergency Calls EROs handling" model are 40 percent urban way, 26 percent rural way and 34 percent motorways which are rated in the simulation via being rural, urban and motorway [121].

-Number of Accidents-(in Function F7 of Part 6.4)

Germany is a best-perform country in EU; so the accident rates for Germany are changing between 2 and 5 per 1 billion vehicle kilometers. (see Table 6.5)

- Section-3: Infrastructure Rates Germany Specific Data-

-Country Population Rates-(in Function FS8 of Part 6.5)

Germany Population which is 80.889 Million [184] is separated into the population groups via city and counties. The separation rates of the total population are summarized in Table 7.17. Country populations are grouped according to population rates.

Table 7.17 Germany Population-Separations with the Code-Letters

Population Size	Existence in Germany (Number of Population Size Rate)	Code-Letter	Population Size	Existence in Germany (Number of This Rate)	Code-Letter
0-19000	1310	A	1.6M-1.8M	0	L
19K-100K	2257	B	1.8M-2M	0	M
100K-140K	168	C	2M-2.5M	0	N
140K-240K	216	D	2.5M-3M	0	O
240K-340K	113	E	3M-3.5M	0	P
340K-500K	91	F	3.5M-4M	0	R
500K-750K	69	G	4M-4.5M	0	S
750K-1M	54	H	4.5M-5M	0	T
1M-1.2M	6	I	5M-6M	0	U
1.2M-1.4M	18	J	6M-7M	0	V
1.4M-1.6M	10	K	7M-8M	0	Y

This is to say, Germany includes the population groups via sizes in 2nd columns and 5th columns. If the process flow in Part 6.5 is remembered; in PF-5, it means the code letters (3rd column and 6th column) are associated with the 2nd column and 5th column in Table 7.17 which are sequenced in the Germany population.

Up to now, Unit Population rates with the code letters are defined and Germany Populations are re-written by Code Letters how many population groups Germany has. At the moment, as it is described in PF-5, Germany population via A, B and C can be defined in Table 7.18. In Table 7.18, Germany population is evaluated with A, B, and C code letters. All other code-letters (in Table 7.17) are also converted to A, B and C code letters.

Table.7 18 Germany Whole Population with the Code-Letters of A,B,C

PSAP Type	Population Size	Existence of A,B,C Populations in the whole Germany Population (61.3 Million)	Code-Letter
X	0-19000	1606	A
Y	19K-100K	3244	B
Z	100K-140K	1368	C

This is to say, in Table 7.18, it is understood how many PSAPs exist in Germany. But these rates give the wrong results. Because the countries in every '0-19000 population' or '19000-100000 population' or '100000-140000 population' does not include the PSAP in Germany. Some small populations are combined with the big size populations such as villages can be combined to the cities. So the PSAP numbers can be decreased. These results are filtrated with the filtration rates A1, B1, C1 and A2, B2, C2 in Part 6.5 in Table 6.14.

-Number of Accident Rates-(in Function FS1, FS9 of Part 6.5)

A Number of road-accidents in Germany in Road Safety 2014-annual report [1] is 299637 which will be the rate of eCall events (nce) via eCall-equipped vehicle after the regulations. On the other hand, "nce" for all public issues for overall 112-PSAPs in Germany is 92M for PSAPs when 70M is false call events [187].

- <u>Section-4: Simulation Results Architecture Optimization Germany Specific Data-</u>

In Figure 7.11, Benefit to Cost Ratio (49, Result-1 in Figure 6.2), Annuity Present Value (48, Net Benefit in Figure 6.2) and Overall System Cost (50, Total Emergency

Costs in Figure 6.2) are summarized as the simulation results for the next generation architectures of Germany to choose the optimal architecture.

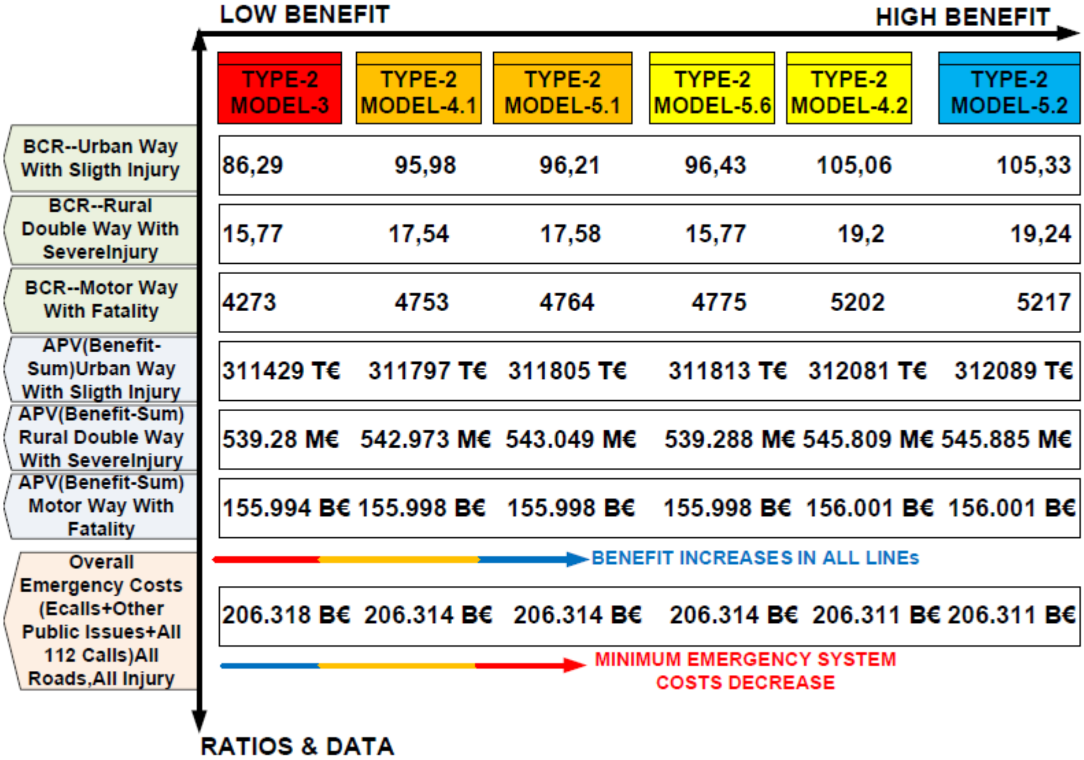

Figure 7.11 Possible New ECall System Architectures for EENA, Model-1; Germany Case

In Figure 7.11, BCR and APV values for three subgroups have the best value in Type-2 Model-5.2. Type-2 Model-4.2 is the second option of next-generation architecture for “Emergency calls EROs handling” in Germany. Next, Type-2 Model-6 can be the third alternative to apply. Benefit to Cost Ratio is changing between 86 and 105 for slight injuries in urban ways (all roads like urban way and all injuries like slight injury) when it is between 15 and 19 for severe injuries in rural double ways (all roads like rural way and all injuries like a severe injury). Moreover, benefit to cost ratio is high as between 4200 and 5200 for fatalities in motorways (all roads like a motorway and all injuries like fatality) which shows the importance of saving life and the difference of accident cost unit rates described in Part ‘Intelligent Vehicle Safety System’. When APV is changing between 311429 T€ and 312089 T€ in urban ways, it is between 539 M€ and 545 M€ in rural ways. Next, it is between 155994 M€ and 156000 M€ in motorways. On the other hand, overall emergency costs are between 206318 M€ and 206311 M€ in all hands.

As a conclusion, Germany can choose the next generation architecture with the sequence as: (i)The best option: Type-2 Model-5.2; (ii) 2nd Option: Type-2 Model-4.2; (iii) 3rd Option: Type-2 Model-6; (iv) 4th Option: Type-2 Model-5.1; (v) 5th Option: Type-2 Model-4.1 (vi) Worst- option of these optimal six architectures: Type-2 Model-3.

CHAPTER 8

DISCUSSIONS

The discussion part of the thesis is a review point of Thesis Conclusions via its numeric results and review of eCall equipped Vehicle System, Case Studies of Country Infrastructures, eCall system and its architectures with the comparison of the literature studies. First of all,the eCall equipped vehicle system is explained by its robustness structure and mounting location strategy of passenger car applications are defined in Part 8.1. The advantage of country infrastructure study part is explained in Part 8.2, where the case study results are compared; and then the case studies are discussed with its final results.

8.1 eCall Equipped Vehicle Discussions

Vehicle Discussion-1: eCall Equipped Vehicle Robustness Working Structure

This thesis from Part 4.1.4 to Part 4.1.6 aims to release the eCall system robustness working principles which will be an obligation after eCall equipped vehicle regulations in Europe in 2018 for passenger cars and light-duty vehicles and after 2018 in heavy-duty vehicles.

According to 6 Sigma design concept in Figure 1.2, Control part of the study which is this section, Part 8 is reviewed with the robustness working principle of eCall equipped vehicle system within Figure 1.4. In Figure 1.4, M-2.2, M-2.4 and M-2.5 describe the basic structure of the study when M-2.1 means the technical background of the eCall system. The new aspect of this study which supports the literature is emphasized in the next paragraph. M-2.3 in Figure 1.4 is the analyze of failures with failure mode effect analaysis and it needs to be released by the Automotive OEM or Tier-1 suppliers after the regulations are applied and eCall devices are produced by suppliers and used in customers in 2018 or after 2018. As a summary of the structure of robustness working, whole parts of Figure 1.4 is released without M-2.3. M-2.3 is needed to be released by Automotive OEM and Tier-1 suppliers when the device is in usage in 2018 for passenger cars and for heavy duty vehicles after 2018 in Europe.

Vehicle Discussion-2: Mounting Location Strategy of eCall Device in Passenger Cars

This study in Part 4.1.7 emphasizes the possible mounting locations of eCall control unit in the vehicle architecture and defining the application possibilities with the analyze of communication sensitivity & electrical connection which will be an obligation after eCall equipped vehicle regulations in Europe in 2018.

The study result is enabled in Part 4.1.7.4 with Table 4.12 and its conclusion-review is given after this table which means Place-L can be the optimal mounting location for eCall control unit of APP1/APP2/APP3 and the other scenarios are also explained; so, the study result is not repeated in this part.

This discussion section, ‘Part 8’ is created;

(i) to discuss this paper results with the comparison of literature publications and patents in the same specific topics, and then the conclusion about the mounting location possibilities of eCall control unit is explained whether the related patent and publications have optimal cases or there can be better situations.

The Mounting location of eCall device is pointed to one of the patent application which defines the eCall device is on the hood side of the vehicle near to the starter battery [197]. This study also analyzes whether this location is the optimal option for eCall device or not. Place-M is the location of eCall control unit mounting positioning what the Gerdes (2013) [197] emphasizes in its patent, and the whole study analyzes in this study shows that; there exist better mounting location places such as Place-L, Place-N/R. The aim of Gerdes (2013) U.S. patent is to set up the eCall device near to battery whether eCall device has a back up battery or not which protects the eCall device from power losses; but this mounting location signal status and cost status is not preferred situation. In addition, due to having high sensitivity in eCall type approvals, the requirements are emphasized for eCall device which means it should not have any power loses in the vehicle system when the device is active [195]. Due to this reason; nearly all eCall devices are produced with back up battery at the current status of the new technologies [161, 201]. As a conclusion, not only the communication sensitivity and electrical analyze via cost status in this study but also the new improvements about back up battery usages shows that Gerdes (2013) aim in its patent loses its importance and there are better options of mounting locations for eCall control unit.

As a conclusion of last part of Part 5 and discussions in Part 6, eCall control unit mounting location is advised, literature support is explained and related publications such as patents, articles are reviewed. The next step of this study aims to search the light duty and heavy duty applications whether the different vehicle applications have the same results or have the different results. Moreover, another future step is the robust working structure including boundary diagram, p-diagram and robustness working principles of ecall device in defined mounting locations.

Vehicle Discussion-3: Cost Reduction Items of Ecall Equipped Vehicle System

The study explains the possible cost reduction items of eCall equipped vehicles. Its results are explained before Discussion Part in Part 4.1.8 and it is not repeated case by case in this section. In this part, a new aspect of literature is emphasized; then, study hypothesis is reviewed.

Firstly; the result of the study 'Cost-effective Emergency Intimation System Design' [75] is emphasized. Its approach is the hardware cost reduction possibilities in different size of the vehicle when this study analyzes the cost reduction with respect to its applications (APPs) with real vehicle sizes.

Secondly; the lack of points in the study of exploratory on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles [121] which is released in 2005 are defined in this study. The lack of points in it are the cost status of eCall equipped vehicles via its technology rates. In addition to them, eCall device and structure in the vehicle system is defined with its value engineering and cost reduction items in this paper.

One of hypothesis of this study is the suggestion of the cost reduction items after eCall equipped vehicle regulations. It explains the vehicle architectures and its developments after eCall equipped vehicle regulations and the result is emphasized in Part 4.1.8 with the cost reduction study results.

Another hypothesis of this study is the whole change points after eCall equipped vehicle regulations of Vehicle Architectures. It is described and its next-generation alternatives are suggested to be an optimal system with respect to cost status and technology for Vehicle Infrastructures.

8.2 Cost Model Study Advantages

The discussion Part 8.2 is created thanks to cost model study of the thesis due to the fact that the cost modeling approach filtrates the architecture and infrastructures with the vehicle, road, and infrastructure information such as country population and road rates, vehicle equipment rate, road situations in the countries, accident probabilities in different ways, time and operational changes in the processes and etc. These parameters are reviewed in the study which is emphasized in Chapter-6, and the architectures which are explained in Chapter-7 are analyzed via being the optimal case or not. Then, the architecture variants are measured in Case Studies and the results in the case studies are covered by the benefits, total costs and etc. The Parts 8.2 and Part 8.7 will make a discussion about the Case Study results and Architecture variants.

8.2.1 Case Study Results

In the thesis, the country and architectures are analyzed via their own statusses after eCall equipped vehicle regulations. When the Case Studies of the Countries are reviewed with each other, there are two common results about the High 'Benefit to Cost Ratio' and High 'Architecture efficiency'.

The applied case-studies in this chapter enables to give a command about the optimal alternatives of the EENA, Architectures. Total Benefit to Cost Ratios, Net Benefits, and Overall emergency service costs are summarized in Table 8.1.

<u>Table 8.1 BCR, APV values are calculated with the BCR and APV values of Countries in its own case studies (with the data in Chapter-7)which are multiplied with the country road rates to measure the net results of the countries.</u>

It is understood that High BCR (benefit to cost ratio) is enabled with the sequence in the countries below (3rd and 4th columns with the rows):

<u>High BCR</u> → U.K. > Germany > Turkey > Italy > Finland

After eCall equipped vehicle regulations, United Kingdom can have better benefit than the others if the advised architecture is applied to the countries.

Table 8.1 Results of Case Studies & EENA Architectures

Architecture	Case Study	BCR_ Min	BCR_ Max	Net Benefit_Min (B€)	Net Benefit_ Max (B€)	Total Cost (B€)
EENA, Model-5	Finland	269,6	476,68	2,45212	2,45784	0,15
EENA, Model-4	Turkey	553,34	742,62	3,918	3,918	17
EENA, Model-2	United Kingdom	1634,7	3012,47	22,522	22,557	50
EENA, Model-1	Italy	475,6	636,1	7,77	7,77	6
EENA, Model-1	Germany	1495,0	1825,66	53,10468	53,4482	206

But; this is not the case shows the clear command to give a general command about EENA, Architecture types. It gives commands about the country and its architecture statuses. Because BCR values are created with the country population and road rates. So the architecture efficiencies need to be sequenced. The architecture efficiencies in Table 8.1 can be sequenced as below (5^{th}, 6^{th} and 7^{th} columns with the rows):

<u>High Architecture Efficiency</u> → EENA, Model-5 > Other EENA, Models

In the efficiency sequence of the architectures, the only EENA, Model-5 is obviously efficient than the other architectures via its net benefit and cost statuses. The other EENA, Models cannot be sequenced with each other because their situations are varied which is associated with population and road rates.

8.2.2 Discussion of Case Study-1, Finland

This study defines the next generation of emergency notification system for ERO-Independent PSAP Model in Finland after eCall-equipped vehicle regulations in 2018. In IEEE conference of ITS 2015, paper "A framework for appraising European Member States' Readiness Level for eCall Deployment" has defined the planned architecture of Finland in its section-2, in which defines the interconnected PSAP with eCall property. These types of architectures are also analyzed in this paper as "Type-2 Model-6" and "Type-3 Model-6.1" with the updated structures and objective evaluations. As it is studied in this paper, these two architecture-types are the 8^{th} and 10^{th} options to be applied in Finland. There are better architecture model-types as it is defined in Figure 7.1 in Part 7.1. The best-option of architecture is the type-3 model-5.2. It includes the same emergency service structure at the current status with the additional structure of manual/auto eCall PSAP. It does not need the interconnected PSAP structure in a new manner.

8.2.3 Discussion of Case Study-2, Turkey

The current situation of Turkey is investigated in the references below,

- EENA Investigations [143],
- Turkey Ministry of Interior Researchers [188]

There is no any other article, journal or technical paper about this study based on Turkey not only in the current status but also after the regulations. The best-option of architecture is the type-2 model-5.2. The advantage of the structure is to be an integrated control room/building concept not only at the current status but also after the eCall equipped vehicle regulations.

8.2.4 Discussion of Case Study-3, United Kingdom

The current situation (Figure 5.7 & Figure 5.8) of study topic is analyzed in the references below,

- European Emergency Number Association [143],
- British Telecommunication [189],
- HeERO Project [119, 120],

There is no any other article, journal or technical paper about this study based on the United Kingdom not only in the current status but also after the regulations.

This study describes the current status and next generation of the topic, the working principles and other references such as EENA, HeERO, British Telecommunication. Then it defines & analyzes the next generation emergency notification system in United Kingdom case study and enables to understand the optimal architectures which can be applied to the country infrastructure after eCall equipped Vehicle regulations in 2018. The best-option of architecture is the type-3 model-2.4.1. When it is investigated, the paper is based on intelligent vehicle and road safety systems, eCall equipped vehicle and country infrastructures including PSAPs and rescue services.

8.2.5 Discussion of Case Study-4, Italy and Case Study,5 Germany

The paper advises the optimal solution of next-generation architecture for “Emergency Calls EROs Handling” Model. Italy and Germany have the same current architecture system in EENA, Models. The only difference is the PSAP is in the police station in Italy when the PSAP is in Fire station in Germany. Its architecture selection is described in Part 7.4 in Figure 7.9 and cost model simulation results are explained in Figure 7.10 and Figure 7.11.

The current situation (Figure 5.2 & Figure 5.3) of Germany and Italy are analyzed in the references below,

- HeERO Project [119-120],
- European Emergency Number Association [143],

There is no any other article, journal or technical paper about this study based on Germany and Italy Infrastructure; not only in the current status but also after the regulations.

This study describes the current status and next generation of the topic, the working principles and other references such as EENA, HeERO. The best-option of Germany and Italy architectures are the Type-2 Model-5.2.

CHAPTER 9

CONCLUSION

The case studies in Chapter-7 and the discussions in Chapter-8 explains the optimal architecture selection and cost model study results for the countries. It is not repeated in this section. In Conclusion part, the sections below are emphasized.

- First of All, new points of literature are emphasized.
- Then, the hypothesis is concluded via their resulted actions.
- In addition to them, the proofs of studies are defined with the applied articles and patents.

9.1 New Points of Literature Studies With The Results

- Vehicle Application Side:

The new aspect of this study which supports literature about the eCall systems is the analyze of eCall systems with its robustness working structure from Part 4.1.4 to Part 4.1.6 when the whole parts of literature are also defined in the study.

Another new aspect of this study which supports literature about the eCall systems is the analyze of the mounting locations of eCall control unit in passenger cars with the application differences via communication quality and electrical analyze based on cost status in Part 4.1.7. The discussions on mounting location such as the patent application which defines the eCall device is in the hood side of the vehicle near to the starter battery is reviewed in this thesis [196] as it is emphasized in discussions in Chapter-8. This paper also analyzes whether this location is the optimal option for eCall device or not. Place-M in Figure 4.12 is the location of eCall control unit mounting positioning what the Gerdes (2013) [196] emphasizes in its patent, and the whole study analyzes in Table 4.12 in this study shows that; there exist better mounting location places such as Place-L, Place-N/R. The aim of Gerdes (2013) U.S. patent is to set up the eCall device near to battery whether eCall device has a back up battery or not which protects the eCall device from power losses; but this mounting location signal status and cost status is not preferred situation as it is shown in Table 4.12 of this study. In addition, due to having high sensitivity in eCall type approvals, the requirements are emphasized for eCall device which means it should not have any power loses in the vehicle system when the device is active [195]. Due to this reason; nearly all eCall devices are produced with back up battery at the current status of the new technologies [161]. As a conclusion, not only the communication sensitivity and electrical analyze via cost status in this study but also the new improvements about back up battery usages shows that Gerdes (2013) aim in its patent loses its importance and there are better options of mounting locations for the eCall control unit.

Moreover, this paper advises the optimal solution of next-generation architecture for vehicle applications. Its vehicle architecture is described in Figure 4.2 and cost study results are explained in Figure 4.12 and Figure 4.15 and in Table 4.12 (in Part 4.1.8). Its optimal solution can be to use as ; (i) internal GNSS and cellular Antennas inside of the eCall device without vehicle antenna in Application-1; (ii) eCall device connector pin-outs as silver pin-outs in Application-2; (iii) eCall device using without company and product remark in Application-3; (iv) eCall device one main connector in Application-4; (v) eCall device mounting in lower cockpit in Application-5; (vi) Aftermarket strategy within whole preparation without eCall device in Application-6.

- Country Infrastructure- Architecture Selection Side:

The Article release of ITS-2015, IEEE [116] which is “A framework for appraising European Member States’ Readiness Level for eCall Deployment” explains the next generation “ERO Independent PSAP” (Finland) advises the next generation of this architecture as interconnected PSAP type. But the result of the thesis in Chapter-7 of Case Study-1 shows that it is not the correct result for the country and its architecture after eCall equipped vehicle regulations in 2018.

The results of the study-HeERO Project (Harmonised eCall European Pilot) [119-120] is analyzed in this study. Its approach for the countries give the definitions about the next generation architectures without any infrastructure details. In this study with Chapter-7, the details of 4 European Countries and Turkey are analyzed in details including architecture details, cost details, and transportation systems. This project is supported via 4 European countries which are explained as an overview of that project reports.

The lack of points in the study of exploratory on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles [121] which is released in 2005 is defined in this study via the infrastructure studies, architectures of EENA,Models and selection of the architecture process. The next generation units of PSAPs are also explained in details via technical, functional descriptions and response-dispatch variants in Chapter-5. In addition to them, eCall device and structure in the vehicle system is defined by its robustness structure and operational requirements.

9.2 The concluded Hypothesis of Thesis Study With The Results

The four items in the Hypothesis part which is the Part 1.5 in the thesis are reviewed and its results are explained with the parts explained below.

- Hypothesis-1: New vehicle system structure including eCall equipment is implemented and its operational requirements are suggested with Robustness Structure of failure mode effect analyze.
  Study in Thesis and Its Comment-1: It is understood that the eCall device will have an architectural overview as it is shown in Figure 4.6, it has a requirements for minimum data set as it is emphasized in Page-49-50, and its hardware schemes, its operational connections are summarized in Table 4.1, its electrical interface are given in Figure 4.3 and the whole information of Part 4.1 is the definition of the eCall device and the eCall system. Especially, Part 4.1.6 gives a clear command of Robustness working principles of eCall structure in the vehicle.
- Hypothesis-2: Mounting Location strategy of Emergency Call Control Unit in Passenger Cars is released via its optimal option.
  Study in Thesis and Its Comment-2: Part 4.1.7 defines the mounting location strategy of eCall control unit in passenger cars. Its optimal positioning and alternative cases are created in Table 4.12. The new released journal is explained in the next section.

- Hypothesis-3: The European country emergency call system architectures after eCall equipped vehicle regulations are suggested.

  Study in Thesis and Its Comment-3: The Chapter-5 of this thesis explains the architectures and their developments after eCall equipped vehicle regulations and the patent application is produced which is explained at the next section of this part.
- Hypothesis-4: The whole change points after eCall equipped vehicle regulations of Current European Emergency Number Association Architectures are described and its next-generation alternatives are suggested to be an optimal system with respect to cost model and technology.

  Study in Thesis and Its Comment-4: The cost model study in Chapter-6 and the Case Studies in Chapter-7 in this thesis explains this item. Its released-article is explained in the next section of this part.
- Hypothesis-5: The cost model approach including vehicle system, road safety, and infrastructural system is advised to decide the optimal architecture selection for the current emergency call systems after eCall equipped vehicle regulations.

  Study in Thesis and Its Comment-5: The cost model study is the Chapter-6 of this thesis and the article which is explained in the next section of this part are created thanks to this chapter.

9.3 Applied Articles and Patents via being Proofs of the Thesis

The first patent application to the Turkey Patent Institute is about the next generation eCall system for EENA, Model-4 which is about Turkey, Belgium, Ostrava, Madrid. Its related parts including functional, technical overview of the next generation units and response-dispatch variants of the services in this study is Part 5.3. The patent number is 2016-00021 called as ‘Kara Taşıtı Acil Çağrı Ünitesi Regulasyonları Sonrası Yeni Mimari Trafik ve Yol Yönetim Sistemi’.

First Article about Italy Case Study is applied to the conference of 2nd International Conference on Vehicle Technology and Intelligent Transportation Systems (SCITEPRESS Digital Library, Thomson Reuters index) with ISBN 978-989-758-185-4, pages 130-137 and Doi: 10.5220/0005908001300137. It is called as ‘Cost Model Approach for Next Generation Emergency Call Systems, Italy Case Study’. Its main point is the architecture selection of EENA,Model-1 for Italy Case-Study which is the part of Chapter-5, Chapter-6 and Chapter-7 in this study.

Second Article about eCall Equipped Vehicle System is applied to the Journal of Science Part-C: Design and Technology of Gazi University which is cited in Tubitak Journals (SCI release) with the paper number ‘5000199004’ called as ‘Türkiye İçin Yeni Nesil Acil Yardım Sistemi’. Its main point is the implementation of eCall system which is the Chapter-3 of this thesis.

Third Article about eCall Equipped Vehicle System is applied to the International Journal of Vehicle Information and Communication Systems with the paper number ‘IJVICS-149319’ called as ‘Mounting Location Strategy of Emergency Call Control Unit in Passenger Cars’. Its main point is the implementation of eCall device and structure in the vehicle with its mounting location which is the Chapter-4 of this thesis.

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FAKRA CONNECTOR CODES

The Codings of the Fakra Connector Types via being Jack and Plug are enabled by the colors and poka-yokes as it is shown in the picture below. This connector is used in this thesis in the emergency call device connection with the cellular and positioning antennas.

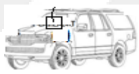
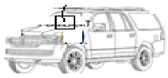
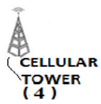
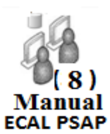
Coding		Jack		Plug		Color/ RAL- Nr.
		Single	Double	Single	Double	
A	Radio without phantom supply/ Radio ohne Speisespannung					Black/ 9005
B	Radio with phantom supply/ Radio mit Speisespannung					White/ 9001
C	GPS: telematics **or** navigation/ GPS: Telematik **oder** Navigation					Blue/ 5005
D	GSM Cellular phone/ GSM Mobiltelefon					Bordeaux/ 4004
E	TV1					Green/ 6002
F	TV2					Brown/ 8011
G	Remote control keyless entry/ Funkfernbedienung ZV (Kessy)					Grey/ 7031
H	GPS: telematics **and** navigation/ GPS: Telematik **und** Navigation					Violet/ 4003
I	Radio controlled parking heating/ Funkfernbedienung Standheizung (SHA)					Beige/ 1001
K	Radio with IF/ Radio mit ZF-Ausgang (Antennendiversity)					Curry/ 1027
L	Not defined Nicht definiert					Carmine Red/ 3002
M	Not defined Nicht definiert					Pastel Orange/ 2003
N	Not defined Nicht definiert					Pastel Green/ 6019
Z	Neutral coding/ Nullkodierung					Waterblue/ 5021

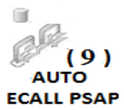
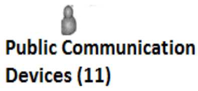
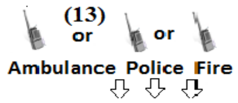
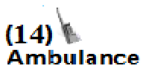
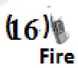
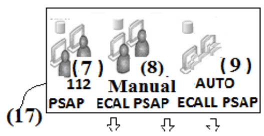
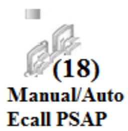
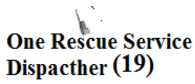
APPENDIX-B

ECALL SYSTEM ARCHITECTURE ITEM NUMBERS

In Table B, the architecture item numbers for different subjects are listed. The first column of the Table B shows the number, 2nd column shos the name of the item, 3rd column shows the figure and the other column is the explanations.

Table B Architecture Item Numbers for different subjects

Number	**Definition**	**Figure**	**Explanation**
1	GNSS Satellite		Satellite Systems
2	Vehicle		Accident Vehicle
3	ECall Device		ECall Measurement and Control Unit
4	CT		Cellular Tower
5	Tree		Accident Object which the vehicle is crashing
6	CN		Communication Network
7	112 PSAP		112 Public Safety Answering Point; Emergency Center
8	Manual eCall PSAP		Next Generation eCall Service giving responses to the vehicles including Manual eCall device

9	Auto eCall PSAP		Next Generation eCall Service giving responses to the vehicles including Automatic eCall device
10	Rescue Service Vehicles		Rescue Team vehicle which reaches the accident places
11	Communication Device		Public Communication Device such as Mobile Phone etc.
12	Interconnected PSAP		The PSAP which is connected to the other PSAPs in the same region
13	One Rescue Service Unit		One of Rescue Services Police or Ambulance or Fire Station
14	Ambulance Service		Ambulance Service Station
15	Police Service		Police Service Station
16	Fire Service		Fire Service Station
17	Integrated Control Room/Building		Control Building can include PSAPs , rescue services, all types of services.
18	Manual/Auto eCall PSAP		One eCall PSAP can be integrated eCall PSAP or one of eCall PSAP
19	Rescue Service Unit		One Rescue Service Unit makes all rescue service dispatches
20	Rescue Station including 112 PSAP		112 PSAP is in one of Rescue Service Stations such as in Police Station, in Fire Station etc.

CURRICULUM VITAE

PERSONAL INFORMATION

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EDUCATION

Degree	Department	University	Date of Graduation
Master	Mechatronic Engineering	Istanbul Technical University	2011
Undergraduate	Mechanical Engineering	İzmir Institute of Technology	2009
High School	Applied Secience and Engineering	Nazilli Highschool	2003

WORK EXPERIENCE

Year	Corporation/Institute	Enrollment
2013-2015	Daimler AG (Mercedes Benz Türk A.S.)	Vehicle Electronis System Components Lead Engineer
2013-2014	Daimler AG (Mercedes Benz Türk A.S.)	Ecall System Coordination Lead Engineer
2011-2013	Ford Motor Company (Ford Otosan A.S.)	Engine Powertrain Control System Lead Engineer
2009-2011	Istanbul Technical University Mechatronic Research Center	Project Coordination and Development Lead Engineer
2008-2009	Bosch Thermotechnick	Product Development Long Term Trainee

PUBLISHMENTS

Papers

1.	Gazi University Natural Science Part-C: Design and Technology	#5000199004 : Next Generation Emergency Call System For Turkey
2.	Inderscience International Journal of Vehicle Information and Communication Systems	#IJVICS-149319 : Mounting Location Strategy of Emergency Call Control Unit in Passenger Cars

Conference Papers

1.	VEHITS	VEHITS’16 ; 2ND International Conference on Vehicle Technology and Intelligent Transport Systems: Cost Model Approach for Next Generation Emergency Call Systems-Italy Case Study

Paper #47

2. IEEE Mechatronics (ICM), 2011 IEEE International Conference : Design and Construction of an Electric Minibus

ISBN: 978-1-61284-982-9, INSPEC: 12144465 Pages: 84-89

Doi: 10.1109/ICMECH.2011.5971239

3. IEEE Mechatronics (ICM), 2011 IEEE International Conference : Conversion of a conventional electric automobile into an unmanned ground vehicle (UGV)

ISBN: 978-1-61284-982-9, INSPEC: 12144575 Pages: 564-569

Doi: 10.1109/ICMECH.2011.5971349

Patents

1. TPE 2016-00021: Kara Taşıtı Acil Çağrı Ünitesi Regulasyonları Sonrası Yeni Mimari Trafik ve Yol Yönetim Sistemi

   (@Research Committee Review)

2. EU Mercedes Benz Türlk A.Ş. üzerinden :

   DE-102015005651-A1: Integrated Electronic Control Unit of Digital Tachograph and Emergency Call System

   (@Research Committee Review)

3. EU Mercedes Benz Türlk A.Ş. üzerinden :

   DE-102015004733-A1: Transfer of DTCO Driver Card Data to Emergency Call Services with Emergency Call Kit

   (@Research Committee Review)

4. EU Mercedes Benz Türlk A.Ş. üzerinden :

   DE-102015005183-A1: Mounting Location of Emergency Call Device and Its Truck Application Method

   (@Research Committee Review)

Projects

1. DPT İTÜ Mekatronik Araştırma Merkezi

   Elektrikli Minibüs Projesi- Araştırmacı

   İlgili Yüksek Lisans Tezi: Elektrikli Minibüs Dizayn ve Üretimi