

AHS Requirements (Phase 0)

Ver. 1.1

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**Advanced Cruise-Assist Highway System Research Association
(AHSRA)**

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Reference I: Report of Creation of Phase 0 Requirements, - Ver. 1.1 -

1. Introduction

1.1 Role of AHS Research and Development

Advanced Cruise-Assist Highway Systems (AHS) research and development is the central theme of Intelligent Transport Systems (ITS). It should lead to the realization of three fields (six user services) out of the nine development fields indicated in the integrated ITS concept. These three fields comprise:

1. Assistance of safe cruising
2. Enhancement of efficiency of road administration
3. Enhancement of efficiency of commercial vehicles

However, the vastness of the scope of application of AHS research and other large obstacles have so far prevented us from achieving systematization of AHS research and development work.

1.2 Flow of Past AHS Research and Development

AHS research has been pursued since 1992, following the three phase development scenario of warning system, prevention system and automated driving system, presently referred to as AHS-*i* (information), AHS-*c* (control), and AHS-*a* (automated cruise) respectively. The features of Japanese AHS include not only AHS-*a*, but also AHS-*i* and AHS-*c*. Presentation of this concept by Japan at the First International AHS Workshop held in San Diego obtained high appreciation from the participating members. The concept involves systematization of AHS research according to specific factors (assistance level and time) and has come to be used as an international technical term used for classification.

However, the activities up until now have been mainly focussed on automated cruise for reasons of easy understanding and of convenience. As a result, an automated cruise vehicle prototype was proposed as a target for research, and seeds-oriented research was promoted. The seeds-oriented (supplier side) approach is essential to AHS related research and will also occupy a substantial part of activities in the future. However, in order for the results of research supported by the input of vast amounts of energy and resources to be efficiently used for the real benefit of society, it is imperative that this research be systematized and guided by the needs of users and society.

Likening the promotion of research to the functional elements in a vehicle, seeds-oriented (supplier side) research can be compared to the engine and needs-oriented (user demands) research to the steering wheel. Research without a steering wheel is like an ocean voyage without a chart, and research and development without an engine like ship with a broken mast. It is crucially important for the research of AHS, as a substantial social infrastructure of the next generation, to be guided and evaluated by both aspects of needs and seeds.

1.3 Creation of Requirements

Based on the above realization, the Advanced Cruise-Assist Highway System Research Association (AHSRA) started to create requirements based on needs. This can be recognized as a process of obtaining an evaluation yardstick used for confirming the direction of research and development, which will be most meaningful both for society and for industrial policies.

The evaluation criteria are obtained by analysis of the needs. Requirements are things described on the needs side and are a written record connecting the needs with development.

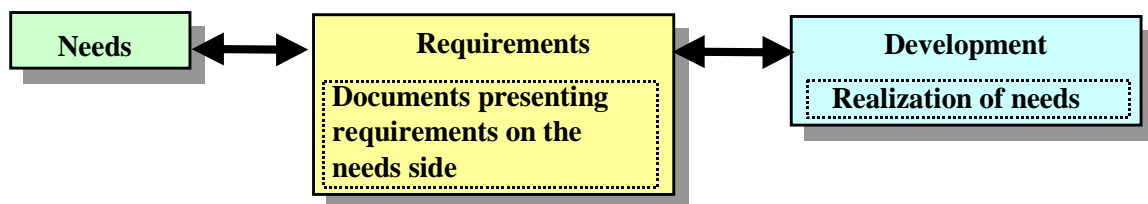


Fig. 1.3-1 Role of Requirements

So far, the needs side has been referred to as an upstream process and the development side as a downstream process, but this does not necessarily mean that the research simply flows down from upstream to downstream like a river. The results of development will be fed back to the requirements to improve their accuracy, which in turn will be reflected in the development. Thus, it is necessary to establish an approach for promotion of bilateral and linked research.

1.4 About this Report

This report is meant to help professionals engaged directly and indirectly in AHS research and development to understand

- (1) The procedure for setting targets to be realized,
- (2) The procedure for the standardization of research and development results, and
- (3) How to appreciate the role of related individual development projects and the way in which they are coordinated.

This is done by reporting the processes for and achievements of creating AHS requirements.

Chapters two, three and four describe the process, purpose and policies for creating requirements, purpose and policies. Chapter five conveys achievements and Chapter six direction of future research and development. This report will help readers understand the origin and principles of research and development of AHS and the directions in which they are moving. Such research proceeds in parallel with work to create requirements. Each Chapter is independently structured, and readers may refer to relevant portions according to their own objectives.

We sincerely hope that this report will be useful for all the researchers of AHS in furthering their recognition and understanding of AHS research and in achieving successful results in their activities.

2. Process of Creating Requirements

AHSRA started work on creating requirements in September, 1997, and completed the creation of Phase 0 requirements in December of the same year. Following the completion of Phase 0 requirements, they are currently being upgraded (quantification/elaboration) to produce Phase 1 requirements.

2.1 Process for Creating Requirements

Creation of requirements has been performed by an organization consisting of a program management team (PMT) and sectional meetings (seven sections consisting of 21 member laboratories) centered on three task forces (T/F); safety, efficiency/environment and miscellaneous. [See T/F member list attached to the end of the report.]

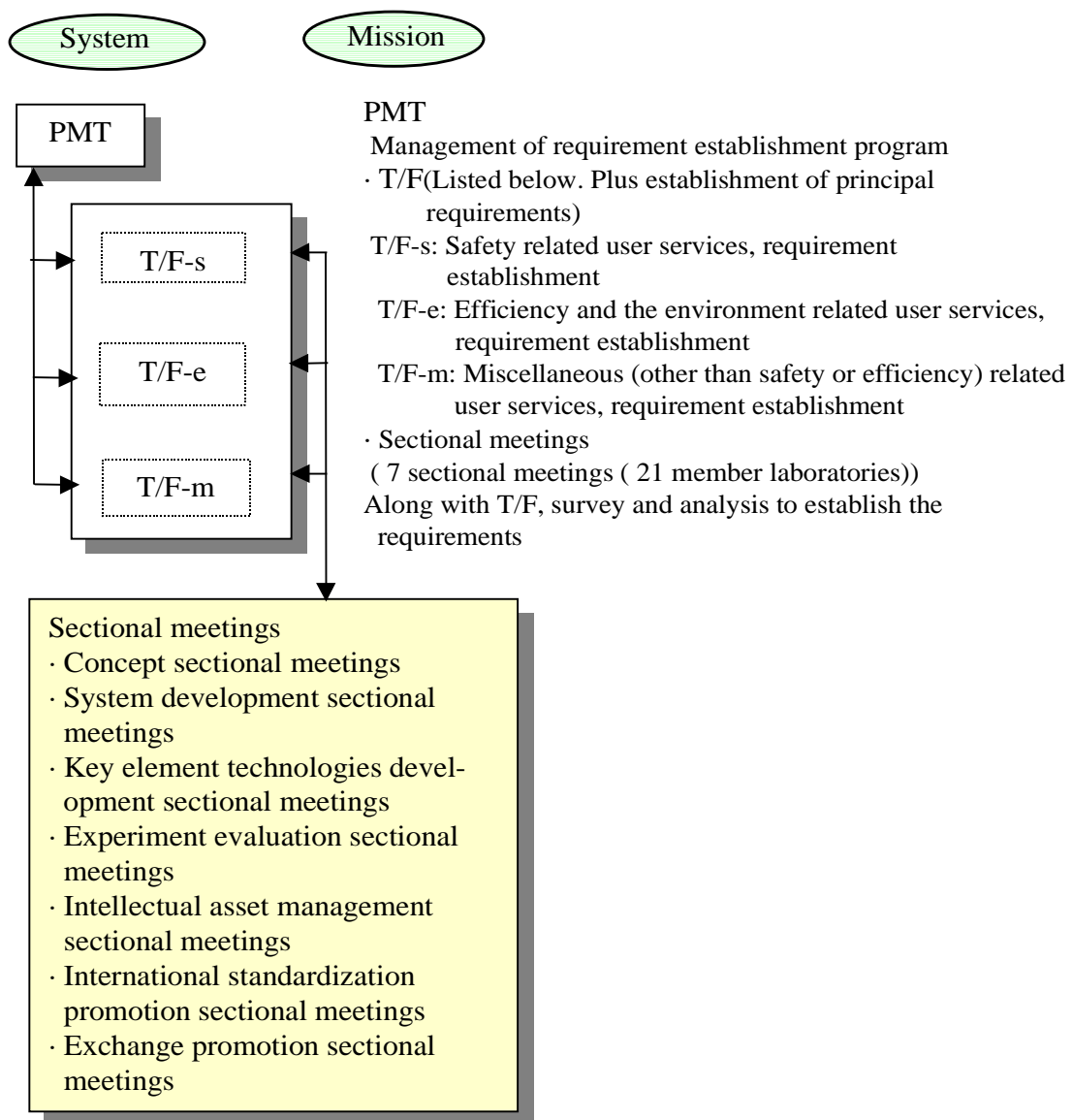


Fig. 2.1-1 Creation of Requirements: Organization and Mission

2.2 Procedure for Creating Requirements

The three task forces extracted the needs for each of the fields *safety*, *efficiency/environment* and *miscellaneous*, and created measures for the realization of needs (user services) and requirements corresponding to such user services. These user services were then evaluated using common classification axes, and the principal user services were established. These requirements were then reclassified using common classification axes, and the principal requirements were established.

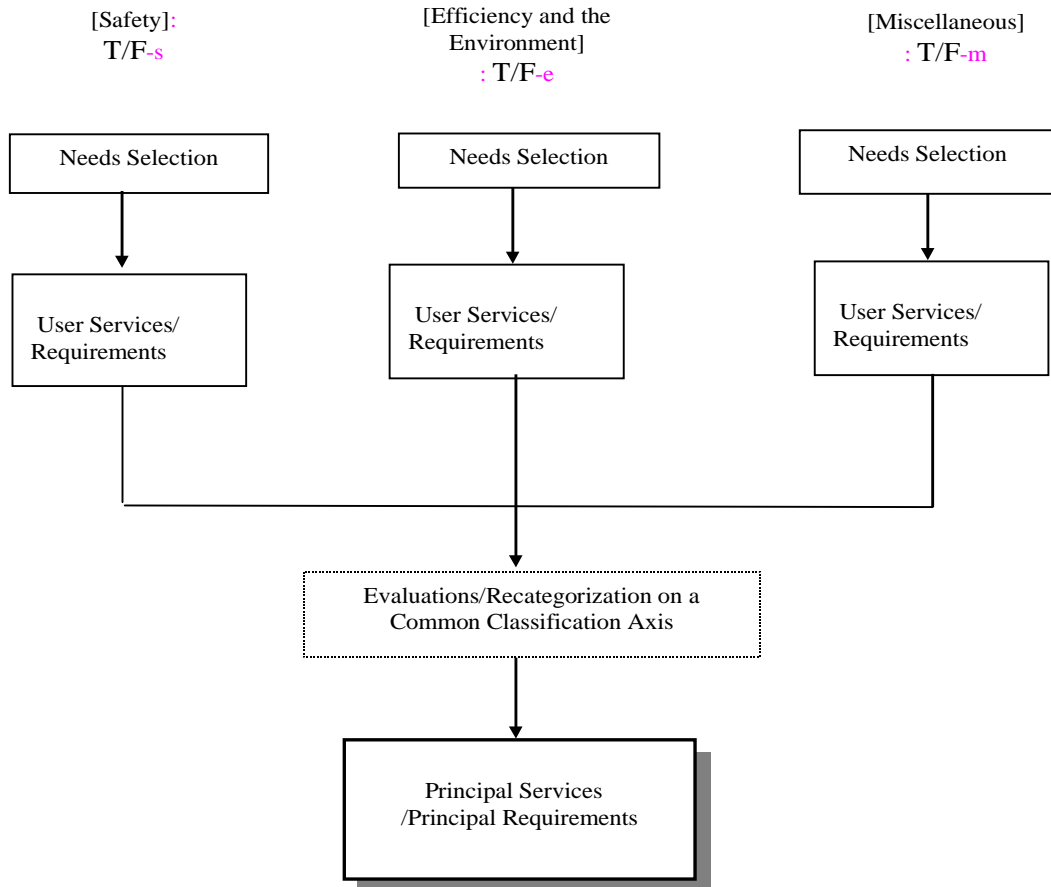


Fig. 2.2-1 Requirements Establishment Procedure

2.3 Schedule for Creating Requirements

Item	Year/Month	97/9	97/10	97/11	97/12	98
Sampling of needs (by field)		←→				
User Services/Requirements (by field)		←→				
Principal User Services/Principal Requirements			←→			
Requirements (Phase 0) Summary				←→		
Requirements (Phase 1) Summary					←·····→	
Requirements (Phase 1) Interim Evaluation						←·····→

(Note) Phase Zero: Requirements described qualitatively.
 Phase 1: Requirements described quantitatively and in detail.

3. Purpose Creating Requirements

3.1 Scope of Study

3.1.1 Concept

It was necessary to define the scope of the study when creating AHS requirements. When creating a document which describes requirements on the needs side (requirements), it does not make sense to presuppose a particular system on the seeds side. The scope of the study must not be influenced by things on the system development side such as the scope covered by existing projects or the features of systems. At the same time, the scope must be defined so that it can be handled as a single block considering the nature of the work involved in the study on the needs side. Here we have established the scope of study with no regard to the existing concepts of so-called AHS systems.

3.1.2 Definition

The scope of this study concerns the improvement of vehicle behavior during five time periods.

This scope is tentatively called cruise assistance, but this does not mean that the scope is defined as AHS. This is a scope for study of needs, and should be considered as being independent from the definition of projects.

3.1.3 Explanation

Five time periods describe the aspects of an accidents and Traffic jams; before, immediately before, during, immediately after, after.

Before an incident happens, assessment of vehicle conditions and the driver's physical conditions, prevention of drivers from dozing off while driving, as well as traffic information and warnings if applicable. Immediately before expected involvement in an incident, issuance of a hazard warning and cruise assistance will be activated. During involvement in an incident, passenger protection systems such as air bags and shock-absorbing vehicles will be helpful. Immediately after an incident, warning for prevention of a multi-vehicle pile up and a fire extinguishing system shall be needed. Afterwards, a mayday system and a driving recorder shall be necessary.

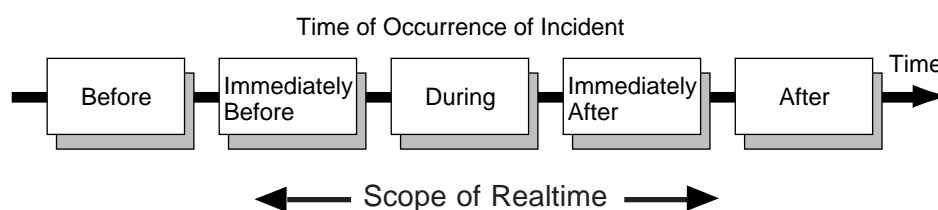


Fig. 3.1-1 Scope of Study

Other portions unrelated to the five time periods have been set outside the scope of the present study, since it is possible to consider them separately from requirements. These others are currently excluded, but may be included at future stages of system development.

Improvement of vehicle behavior means improvement of acceleration, deceleration, steering wheel operation and includes not only automatic control of the vehicle but also manual control performed by man.

Behavior shall be classified into three fields; longitudinal, lateral and intersections (a complex system such as an intersection where traffic streams of vehicles and pedestrians cross).

3.2 Purpose of Study

Requirements are required performance specifications which are related to those necessary functions described in order to reflect social needs in the system development. The purpose of the present study is to determine evaluation criteria for guiding the research and development in a direction meaningful for both society and industrial policies.

The present study includes the following items:

- (1) Analysis of social needs, clarification of a system for user services
- (2) Description of requirements along with a system for user services (However, Phase 0 requirements are limited to qualitative statements only.)
- (3) Presentation of a direction for future research and development which moves in parallel with the system for user services

Clarifying the details of these items will help promote research moving in the same direction, without regard to upstream or downstream processes.

4. Policies for Planning Requirements

4.1 Purposes of Advanced Cruise Assist Highway System and Scope of Study

The main purposes of cruise assistance are enhancement of safety and improvement of efficiency/environment. Needless to say, enhancement of safety and improvement of efficiency/environment will not be realized by cruise assistance alone, but by the combination of this with other measures. Here we handle only that scope which can be realized by real time vehicle behavior.

For example, with respect to safety, we do not handle here education of drivers, though the topic is of great importance. Similarly, we do not handle improvement of efficiency/fuel consumption by rationalization of distribution channels when considering the improvement of efficiency/environment.

Peace of mind, comfort, labor saving, convenience, etc. could be considered as well, but these are either secondary purposes satisfied when the above two purposes are achieved, or purposes achieved as a result of practical application. We shall consider these if and when necessary.

4.2 Separation of Principal Items and Application Items

One of the greatest achievements in the present study is establishment of a system for the principal user services which separates principal items and application items.

For some time, there have been various attempts made to connect the analysis of needs (upstream processes) to system development (downstream processes). However, it was not easy to make a user service system which, while not being influenced by system development, is meaningful for the classification of development levels. That is to say, a user service system, which in a sense, has conflicting aims.

In this study, we evaluated and reclassified user services and requirements which were investigated by the three task forces using common classification axes. While doing this, we extracted universal items regardless of component technologies or systems, and arranged them into principal user services and principal requirements. We then separated these into a service package and application requirements items, which are related to services that are actually provided (Table 4.2-1).

Here we have solved the above-mentioned problems related to systemitization, by creating a service package that is a combination of principal user services. (This will be further elaborated in Chapter 5.)

Table 4.2-1 Basic Items and Application Items

	Basic Items	Application Items
Meaning	Universal items not dependent upon element technologies or the system	Items related to actual services provided
User Services	Principal User Services	Service Package
Requirements	Principal Requirements	Application Requirements

We have thus been able to establish a system of principal user services which should become the most fundamental classification for future research.

4.3 Handling of Other Items

We have employed principal user services as a means for classification in the present study. There are, however, other items that should be considered in the course of promotion of research and development such as

- Separation of AHS-*i*, AHS-*c* and AHS-*a*,
- Allocation of functions to vehicles and infrastructure,
- Kinds of roads (the extent of coverage of dedicated or ordinary roads), and
- Kinds of vehicles (the extent of coverage of passenger cars, buses, cargo vehicles, etc.).

The presence of these classifications, which are worthy of consideration, has made the discussion of systematization of a cruise assistance system more complex and diversified. Principal user services is the most basic classification which runs parallel to social needs, and is appropriate as the principal classification for research.

Other ways of classification concern the method of creating systems and should be used for secondary classification. For instance, AHS-*i*, AHS-*c* and AHS-*a* represent methods of carrying out services or levels of assistance. Allocation of functions to vehicles and infrastructure is related to the problem of selecting methods for the realization of services. These are issues that can be appropriately selected according to the level of technology or cost during system development.

4.4 Cooperation with Other Projects

As stated in 3.1 above, there is no specific relationship between the scope of the present study and actual projects under development.

As the principal items have been created by extracting and then classifying universal items, regardless of the component technologies or systems, they should be handled as universal items irrespective of projects. They are expected to become the common ground for various projects. For example, sharing of data and experimental equipment, making the principal requirements common, and standardization are all important. This should apply equally to the international scene.

The application items can be adjusted and handled differently for each project. They include not only existing public projects, but also product development by private corporations. Research and development of application items can be allocated separately to separate projects. There will also be cases where development on a competitive basis is efficient. However, it is important that the interoperability between systems be assured, in order not to hamper generalization and universal use.

It is desirable to coordinate domestic and interrelated development projects as a whole, by assuring common sharing of principal items and interoperability related to application items. It is also important to promote international standardization.

This report should be used as a step toward such objectives. Further coordination is required between various development projects in the future.

5. Achievements of the Creation of Requirements

Here we discuss the achievements of AHS Requirements (Phase 0) in more detail. The basic concepts will be explained at first (Section 5.1), followed by descriptions of principal user services (Section 5.2), principal requirements (Section 5.3), service packages (Section 5.4) and application requirements (Section 5.5).

5.1 Basic Concepts

A flow chart of the development of a cruise assistance system envisaged in the present study is shown in Fig. 5, 1-1. The numbers attached to the blocks correspond to the numbers of the sections in this chapter. The user needs are the source of every study. The needs related to AHS have been widely surveyed and studied, dividing them into enhancement of safety, improvement of efficiency/environment and miscellaneous. Not only obvious social, organizational, institutional and personal needs, but also potential needs have been included. For example, with respect to safety, even though they did not result in an accident, cases of unsafe situations involving feelings of fear and relief are included in the study.

Continuing, individual user services which realize the user needs are listed. Here principal user services are mixed with application user services. These were analyzed and the principal user services (principal service elements which are common to a variety of services) were extracted and organized into a system. The principal requirements were obtained as elements of basic user services. Items for the principal requirements correspond one-to-one to those of the principal user services.

The principal user services and the individual application services are combined (packaged) together to make draft service packages. Here the packaging has been done on the basis of individual user services, but the service package will be supplemented from time to time with new items according to future research progress and situation changes.

The elements necessary for service packages are the application requirements. The application requirements comprise of principal requirements and individual and additional requirements. The application requirements bridge the upstream processes and the downstream processes in a concrete, realistic way. System development and development of component technologies is promoted, evaluated and put to practical use according to these application requirements.

The principal requirements should become the principal portion of standardization of human machine interfaces (HMI), etc. The applied portion of standardization of interoperability among systems will be borne primarily from practical system development.

For the present AHS Requirements (Phase 0), the portion inside the dotted line square of Fig. 5. 1-1 has been sorted out.

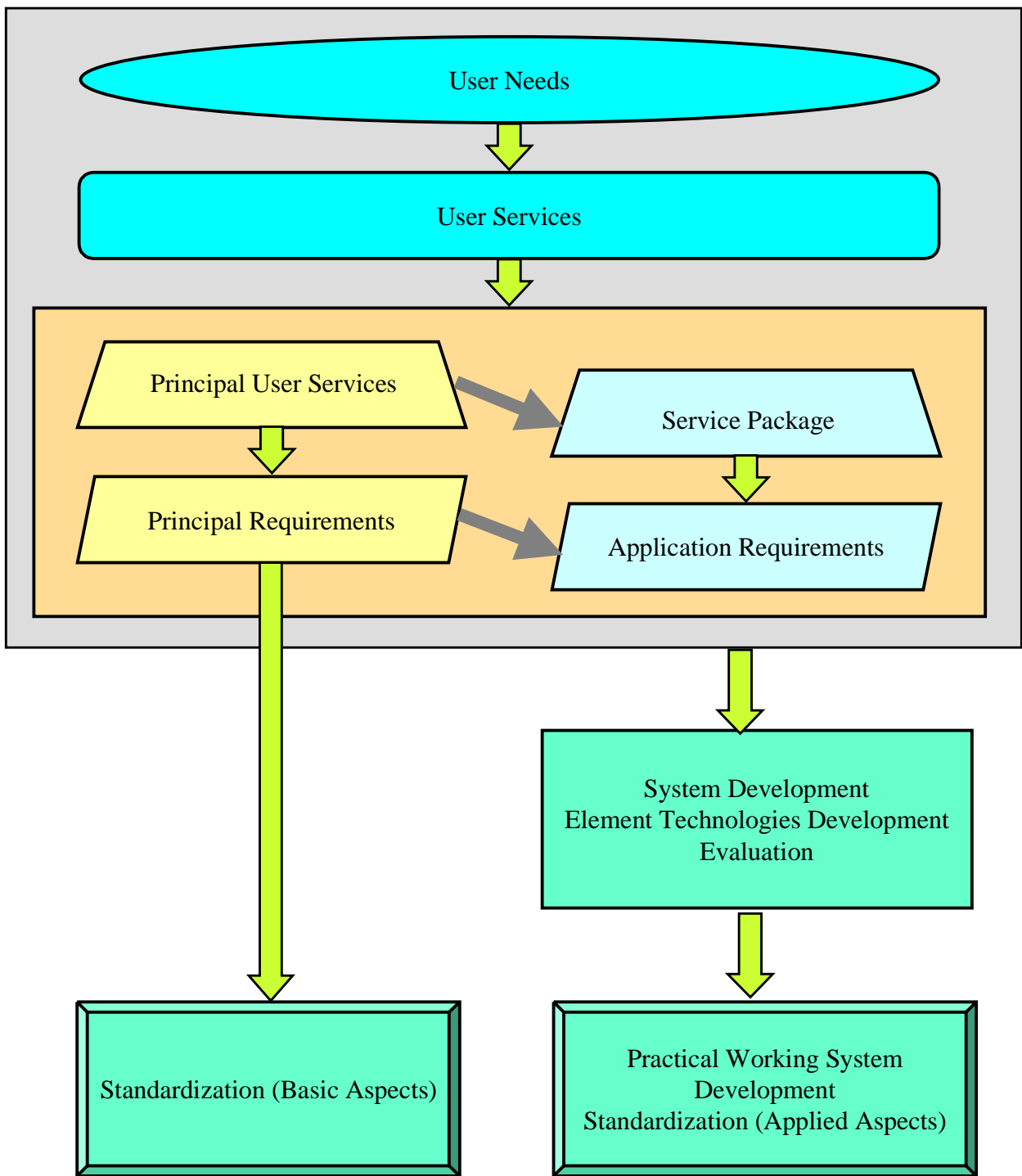


Fig. 5.1-1 The Development Flow of the Cruise-Assist System (Outline)

Fig. 5. 1-2 shows the concept of principal items and application items using an example involving sandwiches. Let's consider a service providing sandwiches to customers. There are diverse needs for sandwiches. The principal user services to answer such needs should be quickly made, easy to eat, required calories can be eaten and delicious. In order to satisfy these four needs in a sandwich shop, the four principal requirements, i.e. cooked within three minutes, easy to handle by hand, 600 calories or above and made to order to individual taste are established, and appropriate preparation methods, equipment and ingredients are procured. The service packages for the products to be offered, such as open sandwiches, hot dogs, clubhouse sandwiches, submarine sandwiches, hamburgers, etc., shall satisfy one or more principal requirements, as well as application requirements such as particular ingredients, side dishes, arrangement on the plate, packaging, etc. In this way, various products can be made and offered efficiently. When it comes to handling of diversified services, it is important to address these by classifying services into principal items and application items.

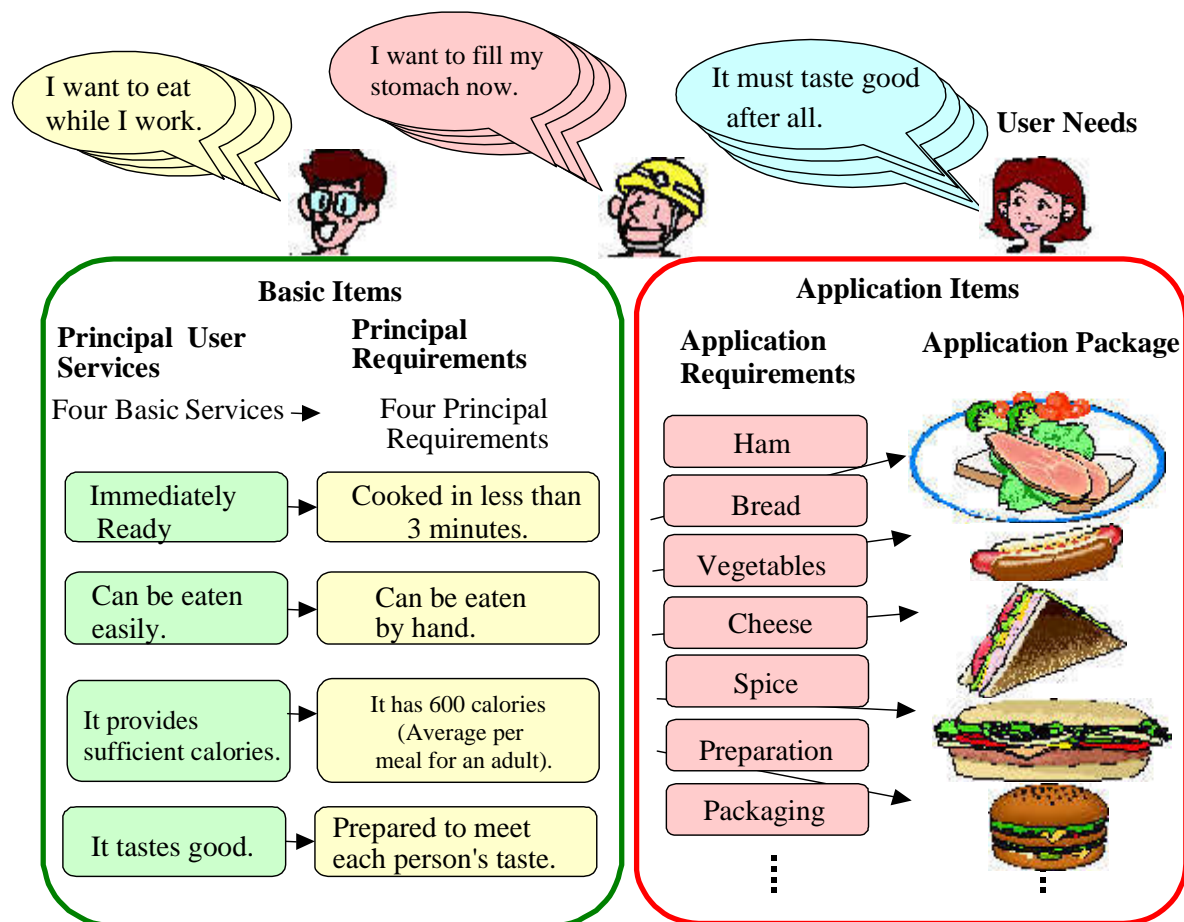


Fig. 5.1-2 Concept of Basic Items and Application Items

Following are definitions and explanations of the various elements.

5.1.1 User services

Services to users (individuals, society, the country, the world, etc.) who have a need for road transportation.

The user services are individual services to realize the user needs. Users extend from individuals to countries, and further to the level of the whole world. Principal user services and application services are intermingled.

5.1.2 Principal User Services

Definition: The principal user services are principal services that can be handled independently in the domain classified according to purpose (enhancement of safety, improvement of efficiency/environment, etc.) and behavior (longitudinal, lateral and intersections).

The principal user services are universal, comprehensive, basic elements derived as a result of study of the details of a number of individual user services. The principal user services, which have been sorted out systematically, are the basic and common elements constituting service packages. The service packages are forms for realization of concrete services.

5.1.3 Principal Requirements

Definition: The principal requirements are the quantitative description of items related to all the necessary functions required for realization of the principal user services. The principal requirements are created in a way that means they correspond one-to-one to the principal user services.

The principal requirements are the basic conditions that should be provided by the principal user services. In the present study (Phase 0), the principal requirements have been described qualitatively. In the future, collection of data and clarification of problems will be pursued to determine the principal requirements in more detail.

5.1.4 Service Packages

Definition: A combination of user services significant (convenient) for society, comprising of one or more principal user services and/or other additional user services.

The service packages are forms of realization of services that answer the user needs in a concrete way. The principal user services are basic functions. It may not be possible to realize each one individually. When offered as actual services, it is necessary to create a service package taking into consideration a combination of services, the place where the service is offered, the practical application to the kind of vehicles concerned, etc.

The service packages are combinations of principal user services matching a given purpose with necessary additional services added. When actually applied to a society, service packages shall be

determined while considering various elements in an integrated manner such as efficiency, cost, technological viability, social viability, synergetic effects with other related services, likelihood of development, etc.

5.1.5 Application Requirements

Definition: A quantitative description of the items related to all the functions necessary for realization of service packages.

The application requirements are a combination of items of the principal requirements corresponding to the constituting principal user services, with necessary additional elements proprietary to service packages added. The application requirements are created in a way that they correspond one-to-one to the elements of service packages.

As shown in Fig. 5, 1-3, when it comes to a service to control headway, it will be necessary to combine the service to maintain safe headway with conditions related to efficiency/environment. If considered from the point of safety alone, the headway should be larger than a certain value (A), in fact, the larger the better. However, if the headway is too large, the efficiency goes down, leading to slow speed and environmental damage. From the point of view of efficiency/environment, the headway should be smaller than a certain value (B). The requirement for the headway in an actual service package will then be any value within the range (C) that satisfies both conditions. In addition, there will be other practical requirements added according to the kinds of vehicles and the roads to which the requirements are applied.

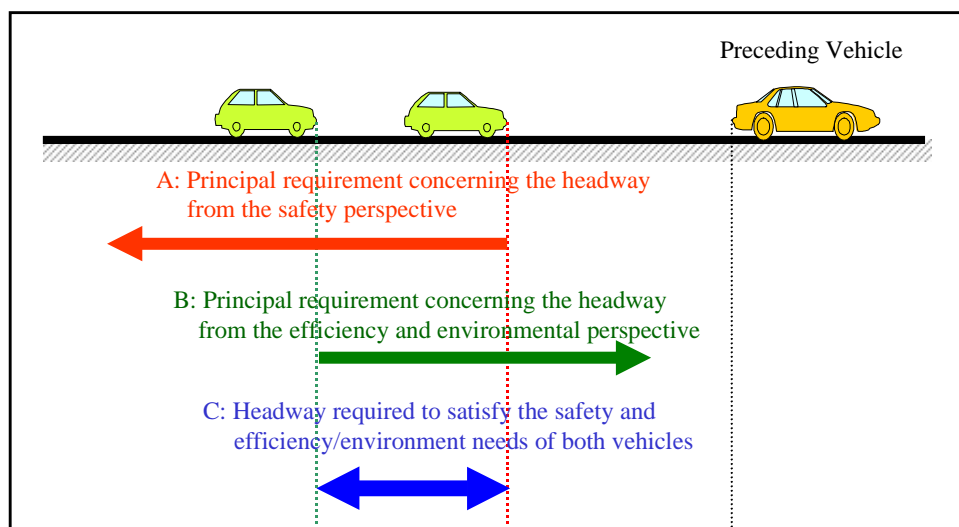


Fig. 5.1-3 Requirements Concerning Headway

5.2 Principal User Services

Here we discuss the details of the principal user services.

5.2.1 Concept of Principal User Services

A system of principal user services derived from the present study is shown in Fig. 5. 2-1. The criteria for which we should consider the user services systematically (comprehensively and universally) are indicated in Table 5. 2-1 below.

Table 5.2-1 System Study Axes

Axis	Explanation	Principal	Application
Goals	Safety, efficiency and the environment, convenience, comfort, etc.	○	
Time Axis (Field)	Before, immediately before, during, immediately after, and after the event, etc.	○	
Behavior	Longitudinal (forward - backward), lateral (left - right), imntersections, etc.	○	
Causes, Counter-measures	Human error, weather, malfunction, etc.		○
Assistance Level	i, c, a, etc.		○
Assistance Method	Infrastructure independence, infrastructure - vehicle cooperation, vehicle independence		○
Place, Application Locations	Single lane, intersections, etc.		○
Function Assisted	Speed assistance, steering assistance, etc.		○
Control Method	Autonomous dispersed, central control, etc.		○

Principal: Axis that can be applied generally independent of the actual service provided.

Application: Axis that can be applied as categories according to the actual service offered.

The principal user services need to be classified and organized into a system using criteria related to the principles. Here we employed primarily purpose and behavior as the main classification criteria. The time axis refers to the time range (field) covered by the services.

(1) safety, (2) efficiency, (3) environment, (4) convenience and (5) comfort are listed as the objectives of ITS. As stated in Chapter two, cruise assistance is considered to have enhancement of safety and improvement of efficiency/environment as its main purposes. Regarding environment (including resources and energy), what will be achieved as a result of improvement of efficiency will be considered. Environment shall be studied together with efficiency as indicated in the term *efficiency/environment*.

Convenience and comfort are often achieved as a by-product of improvements in safety or efficiency, and are handled in the study when necessary under others. These also enhance and improve efficiency of road administration.

With respect to behavior, (1) longitudinal behavior, (2) lateral behavior and (3) intersection behavior are used as the basic actions of vehicle traffic.

Longitudinal behavior includes actions aimed in the directions in front of and to the rear of the vehicle, and includes adjustment of speed or headway, and avoidance of collisions by deceleration/ stopping. Lateral behavior includes actions aimed left and right of the vehicle, and includes staying in lane and lane changing. Lane changing includes avoidance of collisions by operation of the steering wheel. Intersection behavior includes actions when crossing traffic streams of other vehicles, pedestrians, trains, etc. It includes right and left turns, avoidance of collisions, diverging and merging, at intersections.

Fig. 5.2-1 shows the result of a systematic study using the classification stated above. We shall verify later whether or not this classification covers the entire picture comprehensively, universally and effectively through the use of accident data, etc.

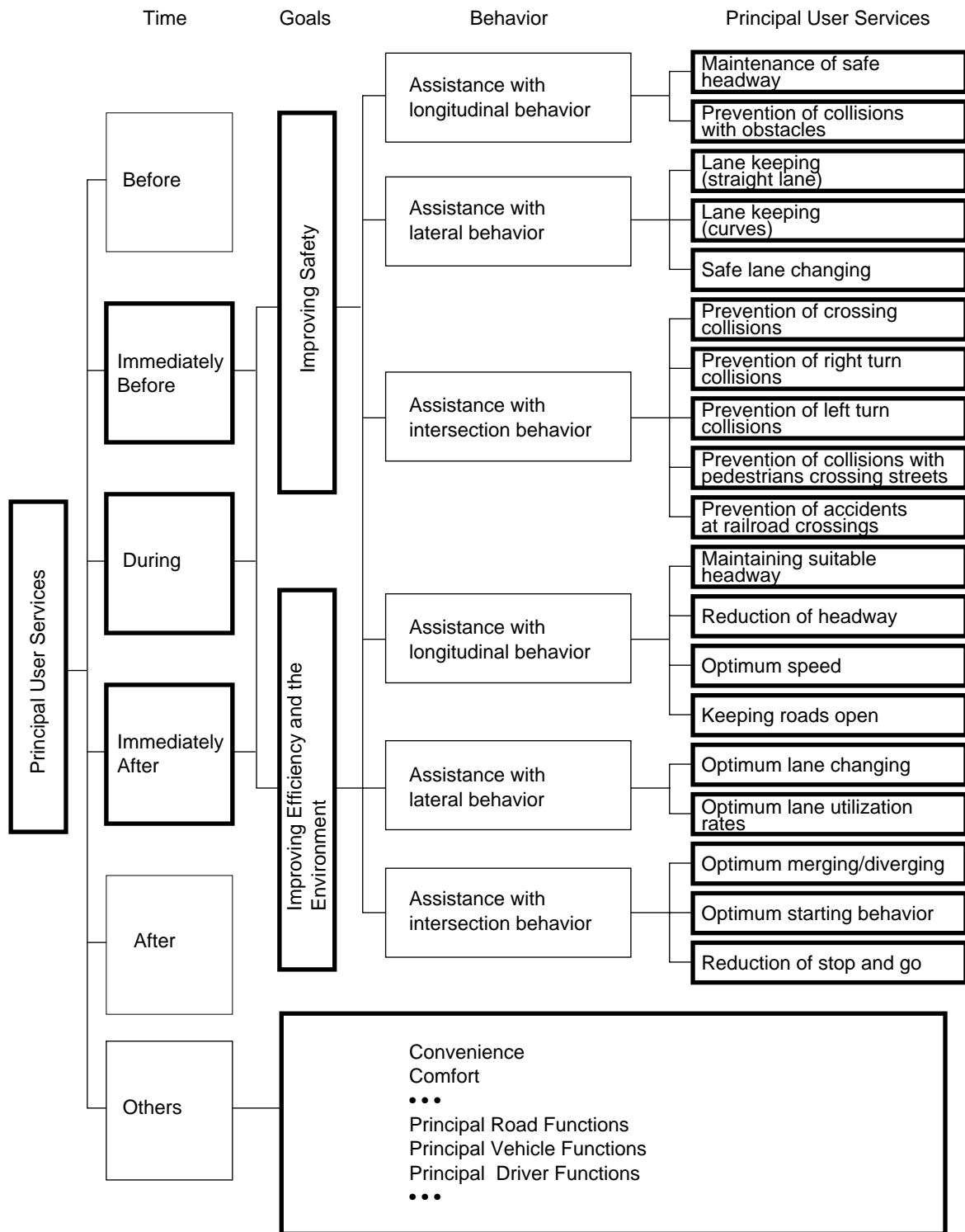


Fig. 5.2-1 Systematization of Principal User Services

5.2.2 Principal User Services for Safety

(1) Creation of Principal User Services

The principal user services for safety are universal services available for all accidents and are created to avoid collisions which arise due to basic actions in the longitudinal direction, lateral direction and intersections.

Table 5.2-2 shows the principal user services and their definitions.

Table 5.2-2 Principal User Services for Safety

Action	Principal User Services	Definition of Services	Note
Longitudinal	Maintenance of safe headway	Maintaining on interval that prevents collision	Preventing collision with a standing vehicle is classified as prevention of collision with obstacles
	Prevention of collisions with obstacles	Preventing collisions with pedestrians, parked vehicle, fallen objects, and other obstacles	
Lateral	Lane keeping (straight lane)	Keeping in lane on a straight road section	
	Lane keeping (curves)	Keeping in lane on curves	
	Safe lane changing	Changing lanes in such a way as to avoid collision with other vehicles	
Intersections	Prevention of crossing collisions	Preventing head-on collisions when vehicles meet	
	Prevention of right turn collisions	Preventing collisions when turning right	
	Prevention of left turn collisions	Preventing collisions when turning left	
	Prevention of collisions pedestrians crossing streets	Preventing collisions with pedestrians crossing street	Preventing collisions with pedestrians crossing a road section with uninterrupted flow is classified as prevention of collisions with obstacles
	Prevention of accidents at railroad crossings	Preventing collisions with trains at railroad level crossings.	

(2) Verification of Principal User Services

In order to verify the appropriateness of the principal user services, evaluation was made through comparison with the patterns in the Institute for Traffic Accident Research and Data Analysis classification according to type of accident of all accidents involving injury or death. Table 5.2-3 shows which items of the principal user services will prevent which accident patterns. Items of the principal user services correspond to either one or more of the accident

patterns without duplication, and thus cover all the accidents. It is evident from this fact that the user services created will become the basis of future packages.

Table 5.2-4 shows how the number of fatalities and injuries by accidents and the amounts of damages relate to the principal user services. The highlighted areas indicate the principal user services of which four are the highest in fatalities, two cause the most amount of damages, and one which contains both (hereinafter referred to as the principal items). These five highlighted items account for 89% of fatalities and 79% of the value of loss. It will be possible to roughly prioritize future research topics using this analysis.

Table 5.2-3 Principal User Services – Accident Category Relationship

Behavior	Principal User Services		Traffic Accident Categorization																			
			Pedestrians		Multiple Vehicle							Single Vehicle										
			While Crossing Street	While Walking on a Street	Straight Lane	Curve	Straight Lane	Curve	While moving	While walking or stopping	Rear-end Collision	Crossing Collisions	Collisions While Changing Lanes	Collisions During Left Turn	Collisions During Right Turn	Straight Lane	Curve	Road Structure/Leaving Road	Parked Vehicle	Fallen Object	Train	
Longitudinal	Maintenance of safe roadway																					
	Preventing Collisions with Obstacles (pedestrians, vehicles, obstructions)			○															○	○		
Lateral	Lane Keeping	Straight Lane			○		○										○					
		Curve				○		○										○				
	Safe Lane Changing													○								
Intersections	Prevention of Crossing Collisions												○									
	Prevention of Right Turn Collisions																				○	
	Prevention of Left Turn Collisions																				○	
	Prevention of Collisions with Pedestrians Crossing Streets		○																			
	Prevention of Accidents at Railroad Crossings																					○

5.2.3 Principal User Services for Efficiency/Environment

A system of principal user services has been studied for efficiency/environment in the same manner as for safety, in terms of longitudinal, lateral and intersection behavior. It is appropriate to use behavior as an axis when making the system, because efficiency/environment also deals with improvement of real time behavior of vehicles. When making a service package, such similar handling will also facilitate creation of a package which should satisfy the safety and the efficiency/environment requirements at the same time.

The main issue of road traffic to be solved for efficiency/environment is assumed to be improvement of the flow of traffic. Lessening of congestion is mainly addressed. This includes reduction of road closure, efficient usage of anticipated traffic volumes, and expansion of traffic volume.

The result of the above study is shown in Table 5.2-5.

With respect to safety, it is possible to examine the significance of the basic user needs and whether or not they are being fully covered by means of data grasped quantitatively such as the number of fatalities and injuries caused by traffic accidents. However, there are no data or systems established for use in the case of traffic congestion. The degree of congestion, travel time, transportation cost, fuel consumption, reliability of expected arrival time, etc. could be considered. It is important to systemitize the use of statistics in this area in the future.

The system for principal user services mentioned above is still tentative and is subject to further improvement in the future based on comments from professional people and results of other studies etc.

Table 5.2-5 Principal User Services for Efficiency/Environment

Behavior	Principal User Services	Principal Requirements	Note
Longitudinal	Maintenance of Safe Headway	Driving while maintaining headway that maximizes the traffic volume	
	Reduction of Headway	Driving while reducing the headway to the allowed range	Reducing excessive headway Reducing the headway when cruising by grouping of vehicles, including a group for private cars
	Optimum Speed	Driving at a speed that maintains an appropriate traffic flow	Cruising at speed Velocity that is close to the maximum quantity
	Keeping Roads Open	Driving when visibility is poor because of bad weather conditions	Assuming dense fog or heavy rain
Lateral	Optimum Lane Changing	Changing lanes without disrupting the traffic flow	
	Optimum Lane Use Efficiency	Driving at a lane utilization rate that maximizes the traffic volume	
Intersections	Optimum Converging/Diverging	Merging/diverging matched to the traffic flow	
	Optimum Starting Behavior	Starting at an appropriate interval	
	Reduction of Stop and Go	Driving at a stable speed close to the average speed	

5.3 Principal Requirements

5.3.1 Concept of Principal Requirements

The principal requirements define the conditions necessary for fulfilling the principal user services. They must be defined logically and universally through sufficient survey/analysis of the causes of problems requiring solution from a social point of view.

5.3.2 Principal Requirements for Safety

The principal requirements corresponding to the principal user services for safety must be created quantitatively through microanalysis of accidents and simulation of vehicles. The Phase 0 requirements have, however, been created on the basis of macroanalysis and using knowledge obtained up to now. Table 5. 3-1 shows the principal requirements for safety.

Table 5.3-1 Principal Requirements Concerning Safety

Behavior	Principal User Services	Principal Requirement
Longitudinal	Maintenance of Safe Headway	Maintaining headway that prevents a rear-end collision with the car ahead when it changes speed
	Preventing collisions with Obstacles	Preventing collisions with stationary objects on the road (pedestrians, parked vehicles, fallen objects, and other obstacles).
Lateral	Lane Keeping (Straight Lane)	Preventing vehicles from lane departure when their driver looks sideways or is inattentive (because of stimulant drugs, etc.)
	Lane Keeping (Curves)	Preventing vehicles from lane departure on a curve because they are traveling at excess speed
	Safe Lane Changing	Preventing collision between vehicles changing lanes with vehicles either beside or behind them in the adjoining lane
Intersections	Prevention of Crossing Collisions	Preventing crossing collisions
	Prevention of Right Turn Collisions	Prevention collisions between vehicles turning right and oncoming vehicles
	Prevention of Left Turn Collisions	Preventing collisions between vehicles turning left and approaching vehicles.
	Prevention of Collisions with with Pedestrians	Preventing collisions with pedestrians crossing at intersections.
	Prevention of Accidents at Railroad Crossings	Preventing collisions with trains at a railroad crossings because drivers fail to confirm that it is safe to enter a crossing.

5.3.3 Principal Requirements for Efficiency/Environment

Table 5. 3-3 shows the principal requirements corresponding to the principal user services for efficiency/environment.

Table 5.3-3 Principal Requirements for Efficiency and the Environment

Behavior	Principal User Services	Principal Requirement
Longitudinal	Maintenance of Safe Headway	Driving while maintaining headway that maximizes the traffic volume.
	Reduction of Headway	Driving while reducing the headway to an allowed range.
	Optimum Speed	Driving at a speed that maintains an appropriate traffic flow.
	Keeping Roads Open	Driving when visibility is poor because of bad weather conditions.
Lateral	Optimum Lane Changing	Changing lanes without disrupting the traffic flow.
	Optimum Lane Use Efficiency	Driving at a lane utilization rate that maximizes the traffic volume.
Intersections	Optimum Merging/ Diverging	Merging/diverging matched to the traffic flow.
	Optimum Starting Behavior	Starting at an appropriate interval.
	Reduction of Stop and Go	Driving at a stable speed close to the average speed.

5.4 Service Packages

5.4.1 Concept of Service Packages

In this section, we shall show the basic concept for creation of service packages and examples of studies of service packages based on this concept. We shall show clearly the direction for future operations and actual results of work done.

In creating a service package, various conditions necessary for its actual introduction to society as a social system must be clarified. In some cases, conflicting conditions will have to be evaluated and selectively screened or prioritized. The services will then be packaged into an actual system, while introduction scenarios, regarding things such as the procedure for introduction and the ability to make the services continuous, will be established.

Shown below are necessary items of study (in random order):

- Structuring of a system in parallel with user needs
- Ability to make the services offered to society (user services) continuous
space-wise and/or time-wise continuity
- Balance between social benefits and cost (social, individual) as a social system
Including both direct benefits and indirect benefits, with negative effects also considered
Assuring individual personal benefits (a will to buy),
Necessity as social capital, etc.
- Technological hurdles and viability of realization (period until realization)
- Social acceptability including legislation, etc.
Will it be accepted by the present and/or future society?
What issues are related to its acceptance? How high are the hurdles?
- Promotional measures, etc.

5.4.2 Contents of Service Packages

The service packages are to be created on the basis of combination of the principal user services studied up to the preceding chapter. They will be named in reference to, for example, cruise assistance on a road with poor visibility, cruise assistance in bad weather, cruise assistance for road administration vehicles, etc. They will be created under the concept described in the preceding paragraph, and will be presented as a package to be introduced as a social system.

Shown below are examples of the service packages arranged from the points of view of assistance of safe cruising, improvement of transportation, road administration, and others.

- Assistance of safe cruising
 - Assistance of safe cruising at intersections: A service to assist the safety of traffic passing straight through, turning right, or turning left at intersections. Structured as a complex

system to prevent crossing collisions as vehicles meet, collision when turning right, collision when turning left, or collision with crossing pedestrians.

- Cruise assistance on roads with poor visibility: This is a cruise assistance service for sections of road with poor visibility such as mountainous sections of ordinary roads, entrances to, or exits from tunnels on highways etc. It comprises of prevention of collisions with obstructions, or prevention of head-on collisions with other vehicles.
- Assistance for staying in lane: This is a service to assure safe cruising within a lane and comprises of staying in the same lane (straight lane) and staying in the same lane (curves).
- Improvement of efficiency of transportation
 - Cruising lane guidance: This aims to reduce congestion by evening out the usage of each lane when there are multiple lanes. It comprises of supply of information, assistance through the use of regulations and, if necessary, safe lane changing.
 - Cruise assistance in bad weather: This is a service aimed at maintaining constant speed by giving preference to AHS vehicles only when normal vehicles are subject to restrictions due to poor visibility, snowfall, or snow coverage etc. It comprises of staying in the same lane and maintaining a certain low speed.
 - Reduction of excessive headway: This aims at improving the efficiency of lane usage. It involves raising the density of traffic in each lane by reducing excessive headway, while maintaining safe headway. It comprises of maintenance of safe headway and, if necessary, staying in the same lane.
 - Assistance with sag cruising: This aims at preventing lowering of efficiency due to congestion arising from a driver's unconscious slowing down at congestion-prone sections of road such as entrances to tunnels, sags, etc. It comprises of maintenance of safe headway.
 - Platoons of commercial vehicles between terminals: This is a service that may be introduced between distribution terminals, providing cruise assistance to a manned or unmanned platoon of commercial vehicles. It comprises of safe headway maintenance, or staying in the same lane, or prevention of collisions with obstructions.
- Improvement of efficiency of road administration:
 - Cruise assistance for road maintenance vehicles: This provides cruise assistance to road administration vehicles, including snowplows and road clean-up vehicles. It comprises of safe headway maintenance, staying in the same lane, and prevention of collisions with obstructions.

- Others

- Smooth cruising assistance: This is a service to provide smooth cruising and improvement of the environment through reduction of energy consumption. This is achieved by reducing the frequency of stopping, starting at times of congestion, and the amount of stopping and starting at intersections and, signals.
- Automated following at times of congestion: This is a service to allow each vehicle to follow automatically the movement of the vehicle in front, keeping constant headway, thus reducing the burden on the driver. It comprises of staying in the same lane and, maintenance of safe headway.
- Automated assistance for stopping in an emergency: This is a service to cause the vehicle to come to a safe stop within the lane or on the hard shoulder, at times when the driver is incapacitated by something such as a heart attack. It is designed to limit to the minimum accident damage to the vehicle concerned and other vehicles around, as well as secondary accidents. It comprises of staying in the same lane, safe lane changing, and prevention of collision with obstructions.

5.5 Application Requirements

5.5.1 Concept of Application Requirements

In the requirements of a service package, there are requirements specified which relate to the realization and introduction of that service package. It is thus necessary to describe, in a quantitative manner, conditions relating to all the functions and capabilities necessary for realization of the service package.

Accordingly, the application requirements will comprise mainly of a combination of principal requirements corresponding to the principal user requirements which constitute the service package. However, certain other requirements that could not be specified in the principal user services will also be included as practical services when necessary. The application requirements are defined to include these additional requirements.

The application requirements are those for realization of services including additional services (practical services). Taking up, for example, the case of cruise assistance for road administration vehicles, the application requirements comprise of (i) a principal requirements part, which consists of a combination of the basic services for control relating to longitudinal motion or lateral motion, motion at intersections, etc.; (ii) an additional requirements part.

The additional requirements part consists of things such as; (a) additional requirements necessary for a road administration system, which concern the operation of vehicles such as snowplows and road clean-up vehicles, (b) requirements concerning the individual performances of the vehicles, (c) requirements concerning the carrying out of snowplowing and road cleaning.

The application requirements must also be established with the potential for further development and continuity of the system taken into consideration.

5.5.2 Contents of Application Requirements

The application requirements will be more clearly specified as research and development progresses in the future. However, in this paragraph, we show for your reference, examples of the application requirements and their details concerning the cruise assistance for road administration vehicles (the example of snowplows is used).

Principal requirements

- Maintenance of headway (similar in details to the principal requirements shown in paragraph 5.3.2),
- Prevention of collisions (as above)
- Prevention of deviation from lane (as above)
- Lane changing (as above)

Additional requirements

– Items related to vehicle operation

Management of location information for the snowplow: accuracy of location information required for management $\pm x$ meters

Timing of and period between information updates: period required for management $\pm x$ sec.

Information for operation management: Name of driver or operator

Information regarding operation time or actual working time: actual figures for travelling time or working time

– Items concerning performance of vehicles

Max. speed of snowplow when travelling: x km/h.

Max. speed of snowplow when working: x km/h.

Volume of snow coverage and working speed, quality of snow and working speed

Max. vehicle height/min. road clearance: $x - y$ cm

Vibration, noise, radio wave noise during operation

– Items concerning operation

Organization of operators, combination of vehicles, number of vehicles for snow removal:

Max. x vehicles

Max. headway when cruising in convoy, max length of convoy: x meters

Role of each vehicle, timing of rotation

Information on restricted areas for dumping of snow

Information on strip at side of road or shoulder

The above example is shown by way of illustration for your reference, although it is natural that further improvement will be made during the process of future studies.

6. Direction of Future Research and Development

A system of principal user services and principal requirements has been made during the creation of the Phase 0 requirements. Further research will be conducted on the basis of these achievements, proceeding in the following three directions concurrently:

- (1) Summarization of Version 1 requirements
- (2) Research on the upstream processes
- (3) Research on the downstream processes

Shared research and activities shall also be pursued in order that these three branches of research can be carried out smoothly (Fig. 6-1).

In the following sections, we will describe the relationship between these three branches of research and the direction for each etc.

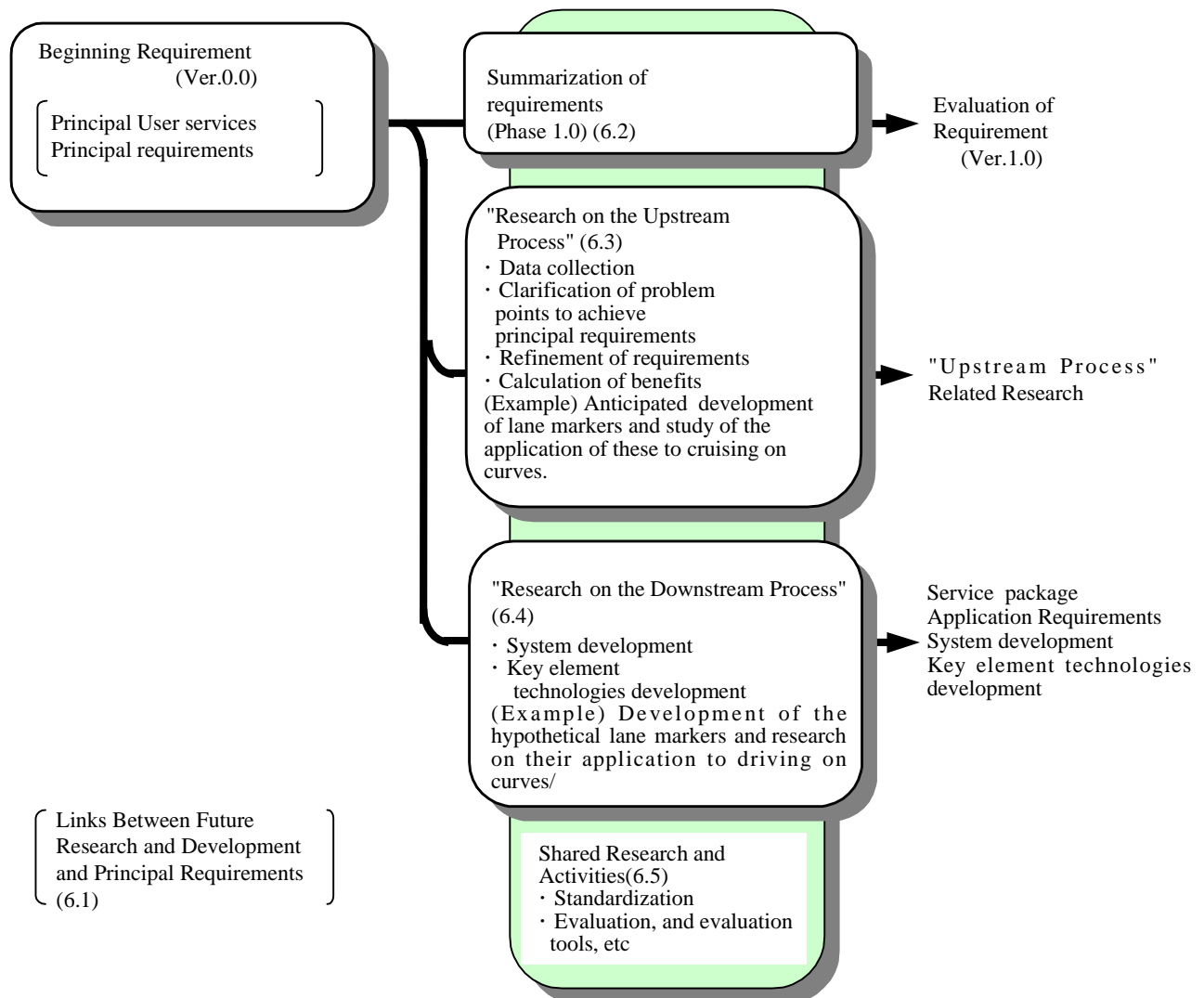


Fig. 6-1 Future Research and Development flow Chart

6.1 Relationship between Future Research and Development and Principal Requirements

– Utilization of the principal user services and the principal requirements as an axis for research and development –

The difficulty of discussing AHS research was due to a lack of a viewpoint on how to sort out the development elements that would allow independent discussions such as the discussion of principal user services in the present study. This is because there were so many real needs. Since the principal user services have been organized into a system in the present study, they will be utilized in all phases of research in the future (Fig. 6. 1-1).

The future research and development shown at the bottom of the table corresponds to each item of research activities in the Flow Chart of Future Research (Fig. 6-1).

The horizontal axes of the table are divided into, from left to right, the categories principal user services, traffic problems to be solved, principal requirements and research and development.

The research and development category is further divided into analysis of road traffic, simulation and key component technologies required. These categories correspond respectively to the scopes of the studies of the various research groups.

The vertical axes of the table correspond to the principal user services. Taking any one of the principal user services, you will be able to trace it to the scope of studies of a particular research group.

[Example]

If you follow safe headway toward the right, you will find that this service relates to collision with an opposite vehicle (vehicle traveling in the opposite direction), which is a pattern of traffic accidents and a part of traffic problems to be solved. If you follow further toward the right, the requirements are explained. The group responsible for these *requirements* will take up the work of quantifying and elaborating them. Similarly, the analysis of road traffic, simulation and key component technologies required listed further to the right will be handled by the corresponding working groups.

The group responsible for the key component technologies required will, after obtaining a certain amount of results, such as those for prospect for performance and cost etc., follow the table back toward the left in order to provide feedback for each related study.

Several research groups can do research on upstream processes and others on downstream processes which allows for feedback.

6.2 Summarization of Phase 0 Requirements

The Phase 0 requirements described in this pamphlet are qualitative statements of the principal requirements, etc. corresponding to the principal user services known at the present moment. These will be made more detailed and realistic through evaluation of research. We will proceed to quantify and verify the principal requirements, moving toward summarization of the Phase 1 requirements, while pursuing verification (particularly in terms of efficiency/environment) of the system for the principal requirements on the basis of the results of data collected, etc. as stated below.

6.3 Research aimed at Upstream Processes

6.3.1 Collection of Data

Collection of data will be performed with the aim of contributing to elaboration of the principal requirements, quantifying of benefits in the upstream processes and evaluating the application requirements and the key component technologies. A quantitative grasping and analysis of present road traffic, relating to safety and efficiency/environment will be made. The collected data will be used as indices to measure the effect of introduction of AHS in the future.

Data suitable for the said purposes must have a certain level of accuracy and must be collected systematically. All possible options for collection of suitable data must be examined, including introduction of outside resources, in order that data can be collected efficiently.

[Example 1]

Gaining an understanding of the number of accidents

In 1997, the principal user services closely related to the number of fatalities, injuries and amount of damages caused by accidents in Japan are

- Longitudinal prevention of collisions with obstacles,
- Lateral lane keeping, straight lane,
- Lateral lane keeping, curve,
- Intersecting, prevention of crossing collisions,
- Intersecting, prevention of collisions with pedestrians.

Fatalities and value of loss related to the above account for approximately 4/5 of those fatalities and value of loss of which the cause is known. Therefore, it is appropriate to advance future research and development for safety using these principal user services as major guidance.

[Example 2]

Clarification of evaluation criteria for efficiency/environment and collection of data

The evaluation criteria for efficiency/environment have not been as clearly organized as the data for gaining an understanding of the number of accidents, leaving some issues regarding systemization unresolved.

In the future, a one-to-one correspondence will be made between the principal user services and the quantitative evaluation criteria that are observable (number, time and converted monetary value), allowing more efficient creation of service packages. It is necessary in the future to carry out systemization in line with this.

6.3.2 Clarification of Problems Relating to Principal Requirements

The purpose of this research is to quantitatively clarify the problems relating to the principal requirements by means of analysis of accidents and congestion on the basis of collected data.

Two points of view are necessary when clarifying problems relating to the principal requirements. One is clarification of where the problems which should be solved lie.

For illustration, a situation involving a driver's recognition of the cruising operation is expressed in the block chart shown below. When clarifying the mechanism of congestion or accidents, etc. it will be necessary to first visualize a chart like this.

When one considers the principal requirements, it will be necessary to clarify in which blocks problems are hidden, through the help of collected data.

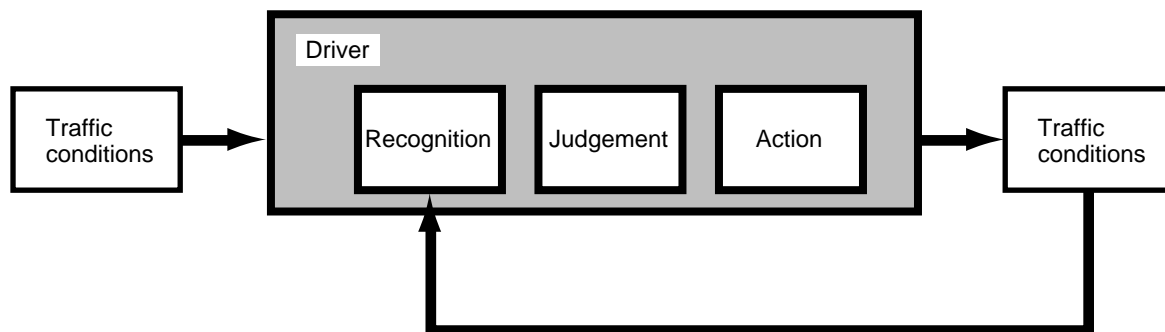


Fig. 6.1-1 Flow of Driver's Actions

The other point of view is clarification of the viability of solution of the problems. With respect to safety, we were able to roughly grasp how each principal user service should contribute to reduction of accidents for each accident pattern, thanks to the one-to-one correspondence of the principal user services to the accident patterns. When elaborating the principal requirements in the future, it will be necessary to clarify the viability of solutions for the problems related to the principal requirements by specifying the relationship between the establishment of variables, etc. and reduction of accidents. At the same time, it will also be necessary to clarify various evaluation criteria concerning efficiency/environment, etc. by means of collecting and analyzing data, etc.

6.3.3 Elaboration of Requirements

The requirements will be created as quantitative numerical targets for the solution of the problems which have been clarified. We described the Requirements qualitatively in Phase 0, but expect to elaborate this to a quantitative description in the Phase 1 requirements, on the basis of data collection and clarification of problems.

Data generated from simulation will also be utilized if necessary in the process of elaboration.

6.3.4 Calculation of Benefits

Calculation of benefits has two aspects. These are social evaluation of the research itself and research of AHS evaluation criteria. Both aspects must be taken into consideration when carrying out research. With respect to the principal user services, direct and indirect damages arising at the present time will be investigated, and their magnitude will be measured in monetary value. At the same time, the relationship of contribution and cost will be clarified, and the benefits (reduction of fatalities and injuries, reduction of damages due to congestion, and reduction of burden on the environment, etc.) for the amount invested will be estimated.

Also, research into improvement of manuals for calculation of cost vs. benefits (e.g. the *ABCD Manual*) will be carried out and a system of evaluation will be implemented.

6.4 Research Aimed at Downstream Processes

6.4.1 Development of Systems

Establishment of service packages and designing of an assumed system will be carried out in order to calculate the technological viability and cost. In order to improve the viability of service packages and the systems, the group responsible for development of each key component technology will also study performance vs. cost. The life cycle cost will also be calculated.

Through such technological support and cost and benefit analyses, the priorities of service packages will be established. As a result, using a service package which has been evaluated as being able to provide benefits, it will be possible to first design the architecture and then establish required performances, etc. for the key component technologies.

The results obtained from this process will be fed back to the upstream process and the downstream process.

6.4.2 Development of Key Component Technologies

The objective of development of the key component technologies is to survey and analyze technological trends, to estimate cost, and to carry out development and evaluation of practical techniques in the fields of telecommunications, sensors, lane markers, vehicle controls, etc., which are required for AHS.

For the time being, the following will be conducted:

- (1) Technological development visualizing the principal requirements
- (2) Technological development required for system development

For technological development visualizing the principal requirements, the following will be studied; technological trends and required level of component technologies considered to be necessary in the future, application of technology, etc. The results will be fed back to the upstream process, etc.

Also, after the principal requirements are clarified to a certain extent, more quantitative component technologies will be developed and evaluated.

6.5 Common Research and Activities

6.5.1 Standardization

The objective of standardization activities is to utilize widely the results of research and to maximize the benefits received from this research from the point of view of international contribution and industrial strategies. It is expected that standardization of the principal part of the cruise assistance system will come from the study of the principal requirements, whereas standardization of the application part (including methods, specifications and equipment) will come from the study of the application requirements.

However, before the results of research are recognized and established as standards, a massive amount of knowledge supporting data and time will be required. Therefore, the activities concerning the standardization will have to be promoted pending establishment of a medium- to long-term vision and strategy. Specifically, at the same time as surveying the situation of international standardization activities at International Standardization Organization (ISO), International Telecommunication Union (ITU), etc., preparation work will be commenced for international standardization based on the results of research into Phase 0 requirements and the upstream and downstream processes.

6.5.2 Evaluation and Evaluation Tools

Evaluation of AHS research activities is broadly divided into two levels, namely a level of individual processes such as data collection, elaboration of requirements, calculation of benefits, development of key component technologies, system development, etc. as well as a level integrating all of these processes.

Persons in charge of evaluation at each of the levels will, concurrently with the surveys and research, specify an evaluation system urgently. Specifically, an evaluation system will be specified by determining the evaluation stages, evaluation ranking, method for evaluation, location of responsibility for evaluation, etc. for each unit of evaluation.

With respect to the evaluation tools, there will be a person who will be responsible for grasping the entire process, and assuring that each evaluation tool will be of a specification that can be utilized by all researches universally. Also, the type of evaluation will be specified by means of experiments,

study, research or simulation to allow systematic evaluation through selection of tools (methods) which have the optimum ratio of effectiveness to cost.

[Example 1]

Evaluation indices for safety and efficiency/environment

The following indices can be considered for safety:

- Number of fatalities from traffic accidents
- Number of injuries from traffic accidents
- Number of accidents
- Insurance premium
- Safety factor (number of fatalities per kilometer of traffic)

The following indices can be considered for efficiency/environment:

- Number of vehicles passing per hour
- Vehicle-kilometers per hour
- Driving hours
- Energy consumption per vehicle-kilometer
- Energy consumption
- Reduction of CO₂

[Example 2]

Social evaluation of system

Social evaluation of a system can be thought of as a system that considers realistic utilization of the system through the use of function, performance and cost or product liability, etc. Cost studies will be carried out for the life cycle cost including the cost for maintenance, etc. When selection of a construction plan is to be considered, there will be study regarding construction cost, cost for land, etc. as well as study regarding local cooperation, disaster prevention, etc.

[Example 3]

Technological evaluation

Newly developed component technologies for information and telecommunications, recognition, control, etc. will be confirmed for reliability, and future trends of function/performance vs. cost will be estimated and evaluated. Also, such factors as ease of mass production and ease of handling of product liability, etc. will be evaluated.

7. In Closing

The AHS research tackles structuring of an entirely new social system not experienced in the past in our country. Therefore, not all the problems arising in this can be overcome by application of traditional empirical practices or introduction of overseas methods. We must, therefore, mobilize all the knowledge available from various fields and areas, in cooperation with persons of professional knowledge. We must apply, quote and develop such knowledge in a flexible manner, while establishing cooperation and coordination with other related projects and overcome the various problems through a process of trial and error.

We are expected, now, to contribute intelligently to the creation of a new sense of values.

Study of AHS Requirements (Phase 0) Ver. 1.1

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