Transition Management of a Risky Technology: Case of Small Unmanned Aerial Vehicles

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Abstract--**Taking the Technology Innovation System (TIS) of small Unmanned Aerial Vehicle (sUAV) in Japan as a case, we extend the TIS framework to understand and manage the transition of risky technologies. In Japan, the environment for sUAV was dramatically changed in 2015 due to an incident of sUAV at the official residence of the Prime Minister of Japan. In December 2015, while amendment of Civil Aeronautics Act (Act) to include sUAV in the scope took effect, the Public-Private council (Council) for improvement of the environment concerning to sUAV business was formed. This paper assumes the Council reflects the TIS of sUAV in Japan and analyses the discourse at the Council to understand the status of the sUAV TIS. Then we discuss how we can manage the transition.**

I. INTRODUCTION

When a technology which are expected to bring economic and social benefit but concerns with and may violate safety and security of citizen's physical, psychological, social and environmental status, how should and can we, that is, policy makers, manufactures, users and other stakeholders involve to and manage the transition? The connection among societies, sectors and technologies is getting complex at today's human and computer intensive systems therefore such risky technologies are increasing.

TABLE 1. EXPECTED SUAV APPLICATION

Segment	Application ideas and examples
Agriculture	Crop dusting, surveillance of harmful animals, precise agriculture
Delivery	Medicines or daily necessities to isolated areas or urban areas
Disaster prevention	Searching, guarding, observation, delivery of goods, restoration of infrastructures, communication relay
Media	Filming
Construction	Site survey, surveillance, replacement of works at a high place
Others	Guard of house, replacement of works at a high place

Small unmanned aerial vehicles (sUAV) is one of such risky technologies. Development of battery and sensor technology since the early 2000' has largely contributed to today's expectation of various opportunities of sUAV application (Table 1). On the other hand, there are big concerns on the safety such as the impact against people, buildings, vehicles, and manned aircrafts and on the security such as privacy threat or intentional attack. Policy makers in many countries are struggling over how to balance social and economic benefit from sUAV application and security of the society.

Technology Innovation System (TIS) framework has been developed in innovation system studies under the needs of a dynamic framework for understanding and managing the formation and transition an innovation system. Previous literatures mainly discussed the effectiveness of the framework to the analysis of environment-friendly technologies, which are often struggling with the competition with conventional fossil-fuel technologies (ex. [1-4]). And the competition is often difficult because environment-friendly innovation is usually less competitive to conventional technologies in terms of cost and share in the market. The situation of sUAV can be different from that of environment-friendly technologies. This paper aims to contribute to innovation studies, extending the application of TIS framework to risky technologies.

This paper focuses on Japanese sUAV TIS, especially recent discourse at the Public-Private council meetings held by the Prime Minister of Japan and His Cabinet since 7th December. However, how to manage the sUAV transition is not a unique issue in Japan but global issues. Even the countries, which have already some regulations for sUAV for years such as Australia, UK and France, are also struggling and keeping discussion for modification and improvement of the regulation. There are still lack of data about both sUAV benefit and risk. Policy makers are lack of knowledge about sUAV technology, some manufactures, users and investors are lack of knowledge about sUAV safety, and experience about safety of sky accumulated in the aviation industry is not able to be transferred directly because the market and players are different. Understanding the built-up and transition of sUAV TIS in a country will highlight knowledge distribution and bring useful information for stakeholders of other countries.

II. APPROACHES

A. the TIS framework

This paper uses TIS framework. The TIS is defined as a "network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involving in the generation, diffusion, and utilization of technology" [5]. TIS approach identified that, for a successful transfer of technology from just an invention to innovation diffused in markets, fulfillment of system-level variables, namely system functions (Table 2), under interaction of stakeholders are necessary [4,6-8].

TABLE 2. FUNCTIONS OF THE TECHNOLOGY INNOVATION SYSTEM (ADAPTED FROM [9-10])

F1) Knowledge development. Mechanisms of learning are the heart of any innovation process.
F2) Knowledge diffusion through networks. Exchange of information is important in a strict R&D setting and can be regarded as a precondition to ‘learning by interacting’ and ‘learning by using’.
F3) Guidance of the search. It refers to those activities within a TIS that can positively affect the visibility and clarity of market and social expectation and will contributes to the process of selection of technologies and resource allocation.
F4) Resources mobilization. It includes both financial and human capital.
F5) Entrepreneurial activities. Risky experiments by the entrepreneurs including new entrants in new markets and new business agency in an incumbent companies, will contribute to knowledge creation and collection and to evaluation of reactions from markets and societies.
F6) Market formation. As new technologies need a protected space before competing with conventional technologies.
F7) Creation of legitimacy. Legitimacy is a matter of social acceptance.
F8) Development of positive externalities. Use of externally pooled labor markets and spill-overs of knowledge developed externally is important.

B. STAMP framework

In the course of analysis, we also use system-theoretic process analysis (STAMP) approach. STAMP is a new safety analysis approach developed in order to enable the analysis of safety of today’s human and software intensive systems [11-14].

Unlike traditional risk and hazard analysis approaches such as Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis (FTA) and Hazard and Operability Analysis (HAZOP), which regard accidents as the outcome of a chain of failure events and as avoidable by increasing reliability of components, STAMP takes system-theoretic approach and considers that safety is one of the emergent properties arise from the interactions among the system components and can be treated as a control problem instead of a reliability problem. Unsafe situations, which are beyond designers’ intentions such as unsafe interactions of non-failed components and human error at cognitively complex supervision of automation, have been recognized [11, 13]. Differentiating safety and reliability is the key characteristics for STAMP and applied widely in aeronautics and astronautics systems (Space system; [12], Air traffic Management; [13], UAV; [14]). On the other hand, the importance of differentiation is not yet largely recognized at the regulation discussion of sUAV.

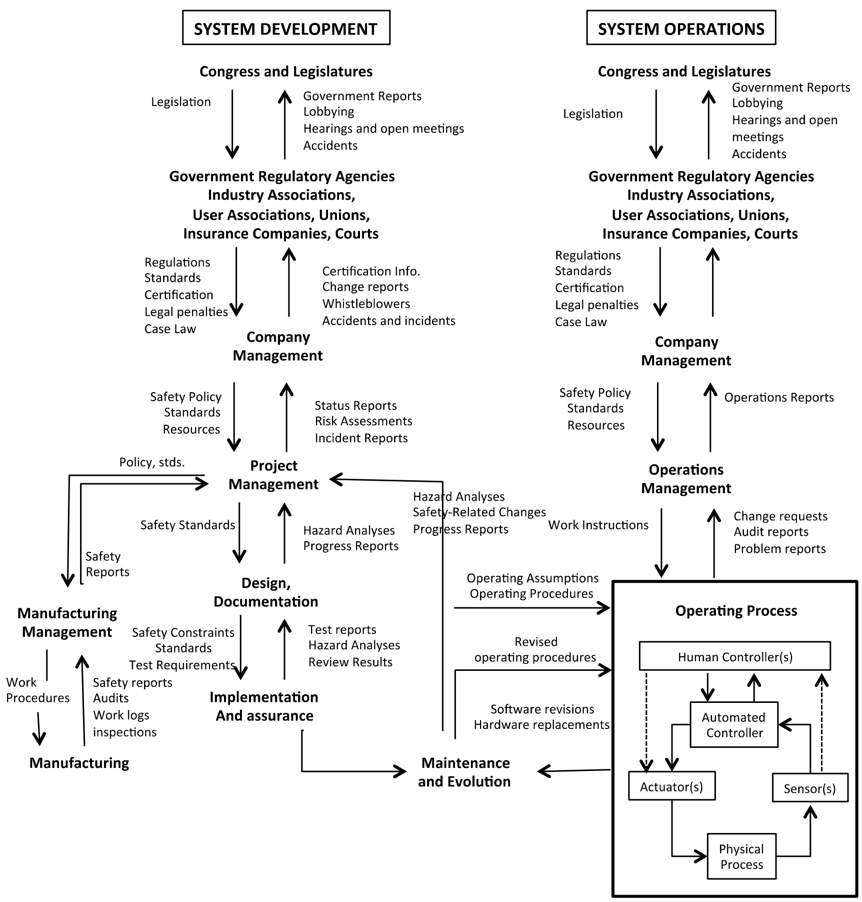

Fig 1. The socio-technical safety control structure of aircraft (adapted from [14])

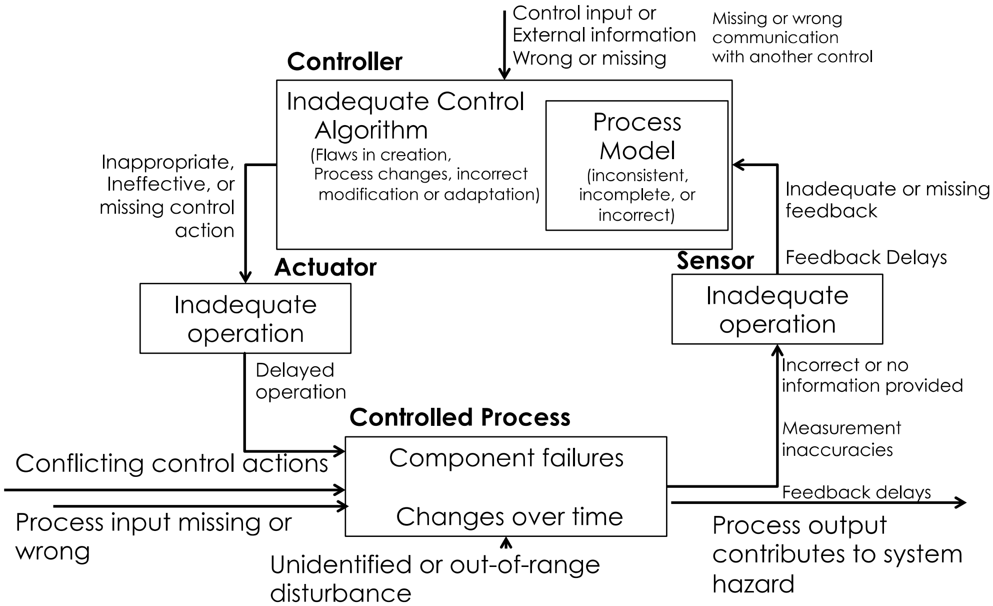

Fig 2. A classification of control flaws leading to hazards (adapted from [14])

STAMP approach viewed the focused socio-technical system as hierarchical structures, where each level imposes constraints on the activity of the level beneath it. Figure 1 shows the socio-technical hierarchical safety control structures of air transport industry. STAMP approach defines accidents and identifies the high-level safety design requirements for the socio-technical system to prevent the accidents. Safety is taken as a control problem and unsafe situations that fail to comply the requirements are analyzed thoroughly. Figure 2 is the chart for users of STAMP approach to identify unsafe situations.

III. CASE DESCRIPTION

A. Background of Regulatory sUAV Discussion in Japan

Until 10th December 2015 when the amendment of Civil Aeronautics Act (Act) took effect, sUAV was out of the Act's scope and there are no particular regulations for use of sUAV in Japan. Absence of proper regulations may result dangerous operations and accidents, and eventually regulators or the society may refuse the use of sUAV one day. Such concerns are one of obstacles for many companies to take full-scale investment on the sUAV applications in Japan.

Recognizing that rulemaking of sUAV is essential in order to simulate sUAV development and eventually for the society to get benefit from sUAV application, a private association, Japan UAS Industrial Development Association (JUIDA) organized their first safety guideline exploratory committee on 20th March 2015. The Japan Civil Aviation Bureau (JCAB) participated in the meetings. A participant from JCAB talked about the background of their participation later at the private conversation; at that time, who will take the responsibility in governments towards sUAV formal regulation was under discussion so that such regulations wouldn't be appeared in near future, and a private safety guideline with the official guarantee from JCAB might serve enough for social demands on a safety guideline for a while. However, the incident that an UAV was found at the roof of the official residence of the Prime Minister on 22nd April 2015 changed the circumstance drastically. The Prime Minister of Japan and His Cabinet held the 1st sUAV conference among related government agencies for regulating sUAV on 24th April. And the amendment to the Aviation Act was promulgated in exceptional speed on 11th September. The safety guideline developed at the JUIDA served as the base of the Act and the guideline published from JCAB.

The overview of the Act and the guidance for safety [15] can be summarized as follows; sUAV operations are limited to day-time and within the visual-line of site (VLOS) and it is prohibited to fly close to populated area and airports. The Act and the guidance can be assumed as the combination of prescriptive and performance-based regulation approach. JCAB will permit sUAV operators to fly out of restricted areas and conditions when the operators guaranteed well the pilot's knowledge such as weather and operations, skill such as emergency maneuver, the fail-safe systems of sUAV at the case of loss of GPS, links and battery, and the organization and the operation system. The permission is made based on the submitted documents. Whenever you get a permission to fly over populated area, you are required to keep 30 meters of distance from people, buildings and vehicles in Japan.

After the amendment, some companies then expressed their worries that strict regulation may spoil business opportunity and eventually the possible economic benefit from sUAV application. On 5th November, the Prime Minister declared that Japan will realizes UAV delivery in three years and instructed government to review obstacle regulations for that. Responding to the instruction, on 7th

December, the Public-Private council for improvement of the environment concerning to sUAV (Council) was formed and number of the meetings have been held since 7th December to discuss the possibility of deregulation and improvement of sUAV related regulations.

B. The Public-Private Council

The first author has been participating to the meetings of Council and the working group for the safety from the beginning. The documents are available to the homepage of The Prime Minister of Japan and His Cabinet[1].

Having the councilor of the Cabinet Secretariat as the chair, the first meeting of council was held on 7th December with vast number of participants from different organizations. Table 3 and 4 show the list of the participants for the first meeting. The authors classified the participants into several groups to show their various positions toward sUAV. The participation from other organizations to the list is possible in the coming meetings if the chair acknowledge the necessity and actually there are additional participants to the following meetings.

The objective of the council is to gather sUAV stakeholders broadly, to catch the fast change and advancement of sUAV business and technology and to discuss for the improvement of the sUAV environment. The council has a goal to reach some agreement in the direction of regulation design in the summer of 2016.

TABLE 3. PARTICIPANTS TO THE COUNCIL (GOVERNMENT)

Involvement to sUAV system	Participating Organizations	Example of involvement with sUAV
Chair	Cabinet secretariat (councilor and counselor)	
Direct involvement with policies	Cabinet Office (CO), Regional Innovation Promotion Bureau; Ministry of Internal Affairs and Communications (MIAC), Telecommunications Bureau; Ministry of Economy, Trade and Industry Manufacturing Industries Bureau (METI), Industrial Machinery Division; Ministry of Land, Infrastructure and Transport (MLIT), Civil Aviation Bureau; National Police Agency (NPA), Security Bureau;	Special Zones with High Potential for Realizing Pioneering Initiatives; Perspective for radio availability; Creation of roadmap, Innovation coast concept; Amendment of the Act; Prohibition of sUAV operation in nationally important areas
Having projects of sUAV	Ministry of Agriculture (MA), Forestry and Fisheries Food Safety and Consumer Affairs Bureau Plant Protection Division; MLIT, Logistics division; Geospatial Information Authority ; Fire and Disaster Management Agency, General Affairs Division	Making a safety guideline for crop spraying with UAV, Promoting other applications; Delivery service projects; i-Construction projects and public; Projects of robotics for disaster
Indirect involvement and others	Ministry of Education, Culture, Sports, Science and Technology (MECSST), Minister's Secretariat Management and Coordination Division; Ministry of Health, Labor and Welfare (MHLW), Pharmaceutical Safety and Environmental Health Bureau, General Affairs Division; Ministry of Justice (MJ), Civil Affairs Bureau; Consumer Affairs Agency, Policy Planning Division; CO (Cyber Security Center, Japan Economic Revive, Information Technology)	Potential of research projects; potential of applications such as drag delivery; Potential concerns; Potential concerns; Potential concerns

TABLE 4: PARTICIPANTS TO THE COUNCIL (INDUSTRIAL ORGANIZATIONS)

Involvement to sUAV	Participating Organizations	Position, action or comments at the Council
Core players; manufactures, operators and the industrial organizations	Japan Agricultural Aviation Technical Center; Association of Precise Survey and Applied Technology; Aerosence Inc; DJI Japan; Japan UAV Association; Minisurveyor; Japan Multicopter Safety Association; JUIDA; Fuji Imvac; Amazon; All Japan Security Service Association; Parrot;	Long experience of sUAV application; Work with MLIT for i-Construction; Manufacture and Provide technology perspective; Manufacture and provide their contribution for application and safety; Provide operation roadmap and technical and safety issues; Provide technical issues; Provide information for safety discussion; Provide information for safety discussion; Manufactures and share their experience; Request of minimum regulations; Request of effective safe standard NA
Holders of special concerns in the regulation perspectives and sUAV itself (and other than core players)	All Japan Air Transport and Service Association; Japan Aircraft Pilot Association; Japan Radio Control Safety Association; Japan Radio Control Model Industrial Association; Japan Model Aeronautics Federation; East Japan Railway Company;	Provide the tangible thread of sUAV to manned aircraft and request regulations; same to AJATSA; Request different regulations for Hobby; Request different regulations for Hobby and Provide their safety approach; Same position to other model aircraft association; NA
Research institutes	The Society of Japanese Aerospace Companies; Japan Aerospace Exploration Agency; National Institute of Information and Communications Technology; NA National Institute of Advanced Industrial Science and Technology	Specialist of Aviation and provide technology issues overview; Specialist of Aviation and provide technology issues overview and research results; Request flexible regulation for their experiment. NA
Others	New Energy and Industrial Technology Development Organization; The General Insurance Association of Japan; Council on Competitiveness-Nippon; Electronic Navigation Research Institute;	Funding infrastructure and robot projects; Provide insurance; Propose use of Innovation Coast at Fukushima for further development
Others; medias,	The Japan Newspaper Publishers & Editors Association; National Research Institute for Earth Science and Disaster Prevention; Japan AD contents production companies association; The Japan Commercial Broadcasters Association; Japan Broadcasting Corporation; Japan Association of New Economy; Japan Business Federation; The Federation of Electric Power Companies of Japan; IoT Acceleration Consortium	Request not violate the right of people to know and a regulation for safety of manned aircraft; Request of Risk Analysis; NA

[1] https://www.kantei.go.jp/jp/singi/kogatamujinki/index.html (In Japanese)

C. The safety concerns

The Council formed the working group for designing the regulations for sUAV safety and the first working group meeting was held on 5th January 2016. Since then, four meetings have been held as of 6th April 2016. The safety is one of biggest concerns for sUAV development as we can see the origin of the amendment of the Act. It is worthy to clear the safety status at the current Act. This subsection takes the STAMP approach and considers the appropriateness of discussion at the working group.

Figure 3 is the control structure of sUAV that the authors consider. This paper focus on an accident of impact to people, buildings and vehicles and consider keeping the minimum distance anytime during the flight is one of important high-level safety design requirements to prevent the accident. We analyze them the risk of violation of the requirement under the Act.

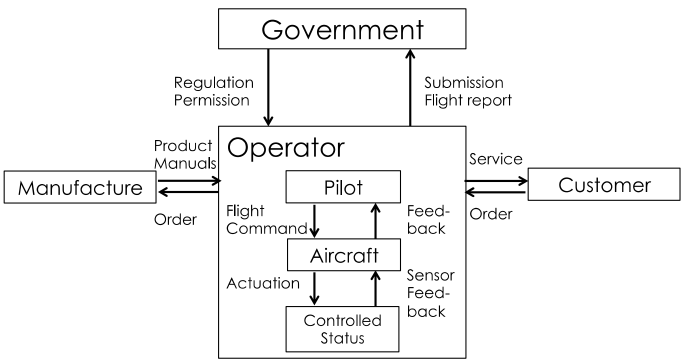

Fig. 3 Control structure of sUAV operation

We can find several points contributing the user to fulfill the high-level requirement in the Act and the guidance. Firstly the Act set 30 meters as the minimum distance to keep. We are going to see the items using Fig. 4, which shows how each item intend to reduce the risk of accident. Once a sUAV operation is permitted the risk of ground impact increase both in the severity and likelihood. Ordering operators to keep the 30 meters should reduce the risk in the likeliness. However, failure in the computer, GPS or the communication lines may happen and disable users to keep the distance. Therefore, the Act request users to have a fail-safe measures including collision impact reducing measures such as parachute on their sUAV when the operator request a permission of flights over restricted areas or at restricted operations. It should serve to reduce the risk in likelihood and severity. And the pilot should be able to make a proper decision and control to keep the distance. At the request of permission of flights over restricted areas or at restricted operations, the operators should guarantee that the pilots hold enough knowledge and skills for control and emergency maneuvers to JCAB. It is expected to reduce the likelihood of the risk. Furthermore, the distance between the sUAV and people, buildings and vehicles should be well monitored. Operation at VLOS and at daytime is the basic and when the operator wishes to flight out of the condition, the operator must keep persons to watch the sUAV.

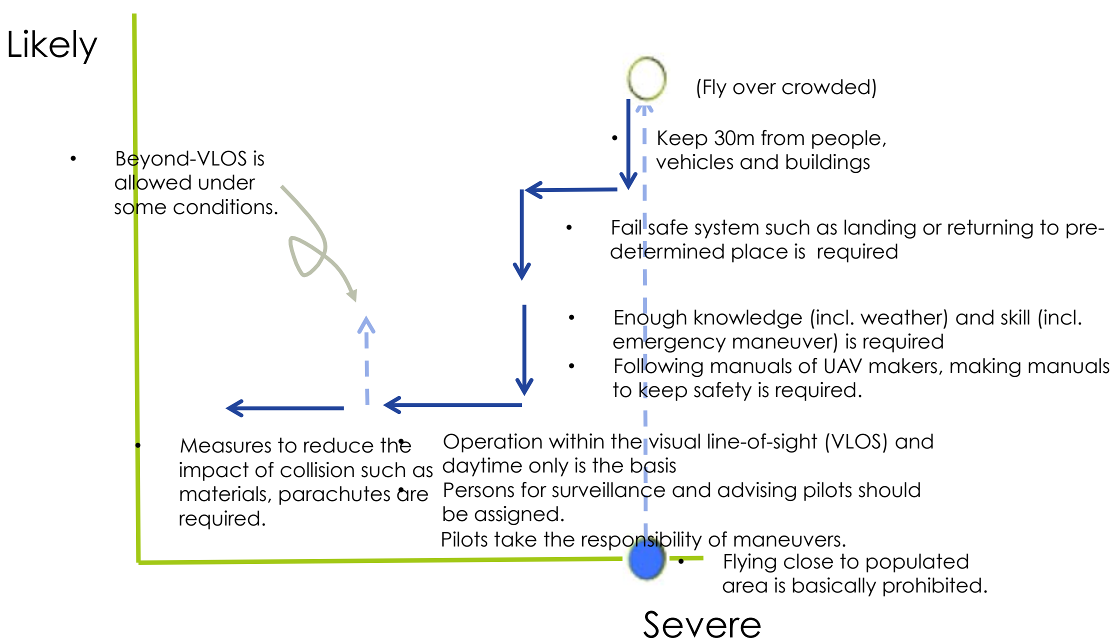

Fig. 4. Visualization of Japanese Aviation Act toward reducing the risk of ground impact

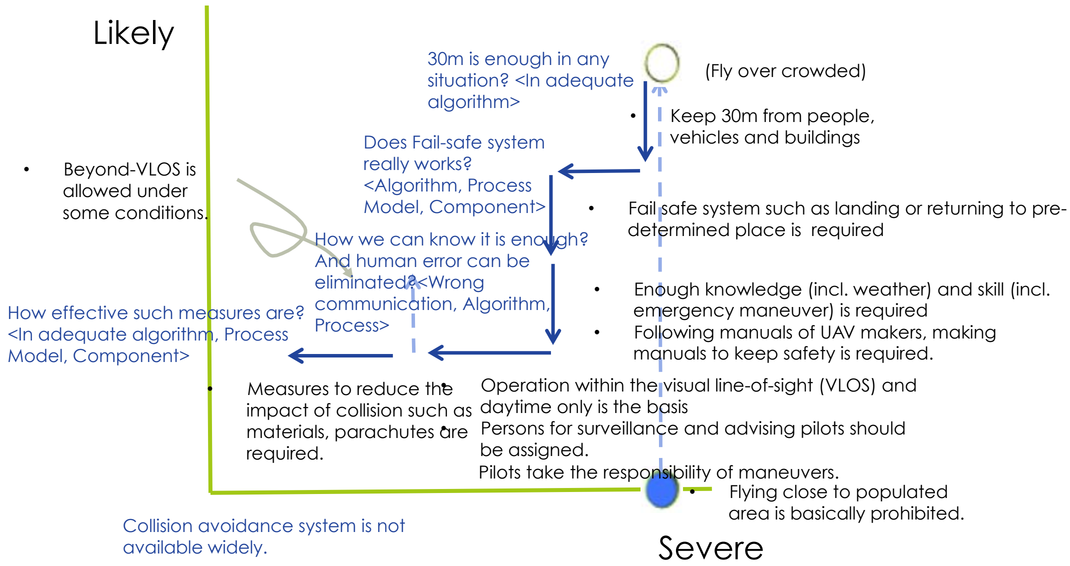

Fig. 5. Safety concerns

We then have to consider if the risk will be reduced properly and enough when people comply the Act. Figure 5 shows the result of our primitive investigation with the chart of Fig. 3, which indicate the safety concerns which could lead unsafe situations even people comply the Act and the guidance.

At the working group of the Council, following topics are raised to discuss; (1) Should we and how can we categorize sUAV and the risk?, (2) Should we and how can we guarantee the safety performance of sUAV? (3) Should we and how can we guarantee the pilot skill? (4) Others such as Collision avoidance to manned aircrafts. According to our STAMP analysis, about (1), we can say that the adequacy of 30 meters and overall risk analysis should be discussed otherwise unsafe situations might be happened although operators comply the regulations. About (2), if the fail-safe system that the operators relied in the case of emergency might not be effective to prevent an accident and we consider measures to guarantee the effectiveness should be discussed. About (3), how can we know the adequacy of the operator through document screenings (and for a flight over non-populated area, there are no document screenings)? About (4), we noticed that collision-avoidance measures are not widely available and should be available for development of sUAV applications.

Although these are still primitive as the research, we can find that there are many to consider the regulations for safety.

IV. TIS ANALYSIS

As of the 6th April, there are three meetings of the council and four meetings of working group for designing the regulations for sUAV safety. We consider the Council is, or at least try to be the sUAV TIS in Japan. Based on the documents opened to the public at the homepage of the Council, we investigated each TIS function. Figure 6 shows the diversity of the opinions and actions at the Council.

For sUAV transition, it is apparent that learning of safety sUAV operation, systems for safety operation, sUAV social acceptance, effective and efficient regulations for economics and society, and diversity of opinions toward sUAV is important (F1 and F2).

Actors to develop knowledge for sUAV (F1) is not limited to manufactures and public users at the sUAV TIS. Because there are various restrictions around sUAV application today, such as Act, availability of radio, and other things that you should negotiate with local governments and society, many of governments are now conducting projects concerning to sUAV application such as public measurement of the terrain, robots for disaster prevention, and sUAV delivery (Table 3). These projects are still at the experimental level and aims to clear obstacles to implement. With the policy of special zone of Cabinet Office, which deregulates some regulatory obstacles for innovation purpose in a selected area, these projects can be assumed also to fulfill the F5.

The Council is one of the place for F2. Not only government but also industrial associations are motivated to serve information at the meetings and have provided their opinions, ideas and some evidence for safe sUAV operations. For example, JUIDA, Japan UAV Association, UAVE and Minisurveyor, in which manufactures or researchers with years of experience on sUAV have central role, considers that one accident of sUAV is enough to damage the future of sUAV therefore are serious about building-up of safe socio-technical system and presented some unmet technology needs, which should serve on of guidance of search (F3). At the council, some manufactures also provide information of their technology and development perspectives so that they might expect to appeal their products and some insist a regulation shouldn't hinder introduction of new technology. Associations for manned aircraft provide information that how the risk of accident of sUAV collision to manned aircraft is real today and ask it clear that sUAV must give their way to manned aircraft. On the other hand, model aircraft teams express that we should differentiate the sUAV regulation between hobby and commercial use in some points. Some of their activities such as a race is affected by the amendment of the Act and worry that further regulation will hinder their culture and they insist we shouldn't make children away from enjoying model airplane with too strict regulation. Media also worries that further regulation may hinder the knowing right of people.

Addition to the unmet technical needs presented by industry associations, METI also contribute to the search of guidance (F3). METI calls for supports to create the roadmap for sUAV, which can be expected to appeal government budget allocation in the future (F4). F3 is very important when the innovation have many uncertainties and also bring investment to the area. So the roadmap and other perspective should be made carefully so that the Japanese sUAV could be competitive to that of other countries. And the guidance should be made to cover necessary topics. For example, risk analysis of sUAV could be scarce at the current knowledge development (F1) and is expected to be encouraged.

Resource mobilization (F4) has started gradually. Before the amendment of the Act, it was said that, large investments cannot be expected without regulation. According to a private discussion with an investor, Japanese investors still thinks that sUAV is too risky. On the other hand, we heard big companies such as Fuji Heavy Industry from aviation industry and Rakuten from web industry recently entered to the industry. Government actions of F3 such as METI roadmap should encourage F4. In further research, we should also compare the status of Japan with other countries.

As we have already noted, there are various experiments (F5). At the commercial applications, cost efficiency is important so that operations beyond-VLOS operation and over populated areas can be required. As it is restricted operation, accumulation of experiments are needed. On the other hand, safety is always important problem and can't be excluded at the experimental operation.

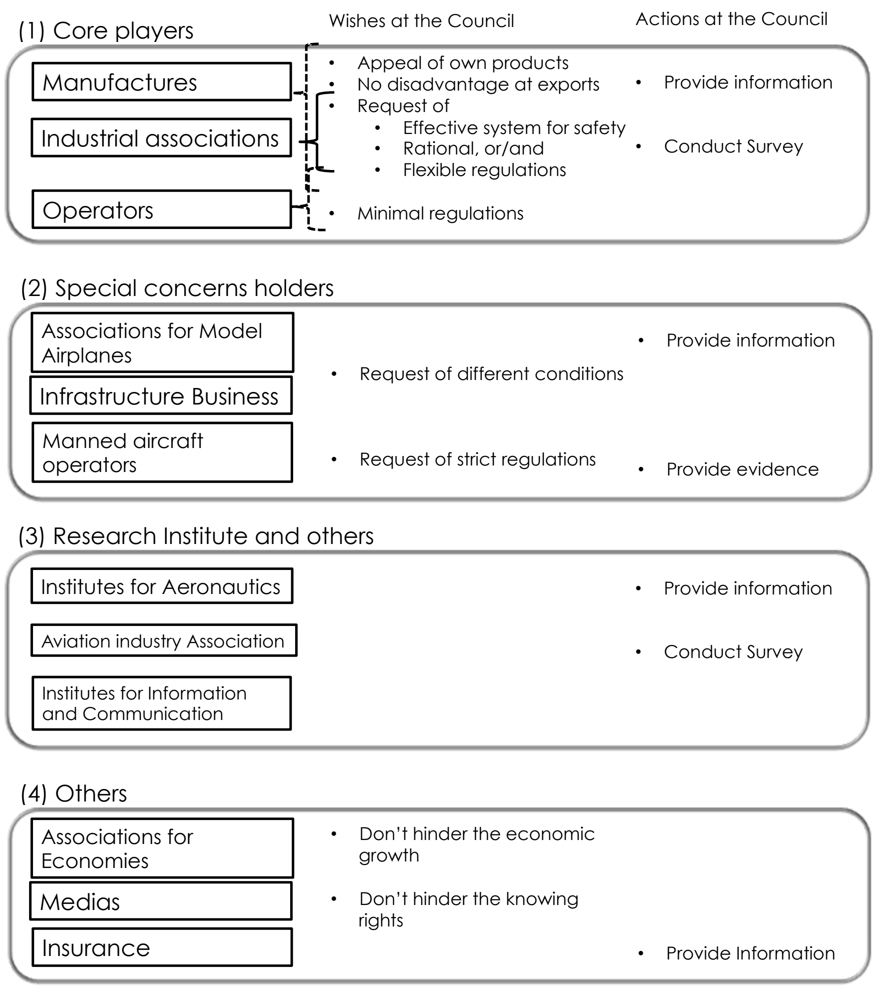

Fig 6. The objectives and actions made by Participants from public

TABLE 5. PARTICIPANTS AND THEIR FUNCTIONS

	F1	F2	F3	F4	F5	F6	F7	F8
(1) Core players	□	□	□	□	□	□	□	
(2) Special concerns holders other than (1)		□	□				□	
(3) Research Institutes and others	□	□	□		□			
(4) Others			□					□
The Council		□	□				□	□
JCAB		□	□				□	
METI			□	□				
Other government agencies					□	□	□	

About market formation (F6), we have already market of hobby sUAV, which was damaged partly due to the amendment of the Act. We also have long history of sUAV industrial application in crop dusting and the market should be also affected somehow by the amendment of the Act. After the Act and considering the development of sUAV technology, we require new protected market for the transition. However, same to F5, safety is important so that extension of experiment and designing protected markets should be done without having safety as out of conditions.

Legitimacy discussion (F7) is difficult. Currently, sUAV development is initiated by the expectation to solve problems for aging society, lack of human resources, and new global competitiveness, safety is very important for the transition of sUAV. Japan is culturally risk averse and it is easy to imagine one early failure of sUAV in terms of safety will lead big wave of social refusal. We need to take careful consideration about safety system while global competition make core players for speedy decision making.

Robotics are one of the positive externality (F8) and METI are now considering the use of the robotics field in Fukushima for sUAV development. Regional economic development is also a key to attract resources to sUAV.

V. CONCLUDING REMARKS

This research is still on-going. In the coming months to the conference, we are going to refine the STAMP analysis and TIS analysis further and we are also going to compare the sUAV TIS in Japan to that of other counties so that we can identify issues to manage the Japanese sUAV TIS. Furthermore, we are also going to see the difference of TIS and the transition between risk technology and environment-friendly technology. Large concerns with the diffusion for the safety is the bottle neck (F7) for the risky technology while the cost and market share (F6) is the bottle neck for many of environment-friendly technology. We wonder such difference may make difference in the application of TIS studies.

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