Chapter 4

Inter-organisational Collaboration for the Safety of Railway Vehicles: A Japanese Case

Takuji Hara

Abstract Shinkansen, the Japanese bullet train, has been operating for over 55 years without serious system accidents. Rolling stock is designed and manufactured through a collaboration between railway companies and contracted manufacturers. Safety is ensured through interactions among organisational actors, material entities, institutions and structures. Safety of such a large technical system in an inter-organisational setting cannot be built by material entities but also requires institutions for coordination, and the mindfulness and leadership of relevant actors.

Keywords Inter-organisational relationships · Safety management · Contracted manufacturing · Japanese railway · MAIS approach

4.1 A Serious Incident

At 1.33 pm on 11 December 2017, the No. 34 Nozomi Super Express (Shinkansen) left Hakata Station, bound for Tokyo. At approximately 1.50 pm, a conductor noticed an unusual smell, which was reported to staff at the control centre. However, due to problems in communication and decision-making, it took more than three hours and 740 km to stop the train and conduct an underfloor inspection, during which an oil leak was discovered. A detailed investigation revealed that one of the bogies had a large crack in its frame and was only 3 cm away from snapping completely. This means that the crack had put approximately 1000 passengers in danger for hours. The Japan Transport Safety Board (JTSB) declared this case as Shinkansen's first "serious incident".

On 28 February 2018, the train car operator, JR-West, explained that when Kawasaki Heavy Industries manufactured the bogie in 2007, they ground down the underside of one part of the frame to correct unevenness caused by imperfect processing. This then weakened that part and caused it to crack due to metal fatigue. The thinnest area of the bottom plate in question was 4.7 mm, in contrast to the

T. Hara (✉)
Kansai University, Suita, Japan
e-mail: t_hara@kansai-u.ac.jp

© The Author(s) 2022
J. Hayes and S. Tillement (eds.), *Contracting and Safety*,
SpringerBriefs in Safety Management,
https://doi.org/10.1007/978-3-030-89792-5_4

standard thickness of 7 mm that is listed in the specifications. According to a press release issued on the same day by Kawasaki Heavy Industries, company policy prohibited any bogie frame parts from being ground down thinner than the standard specifications, and a notice to this effect had been posted at the time. However, the worker responsible was unaware of the policy, and the foreman did not check the work after completion. The company's investigation also revealed microscopic flaws in the bogie frame, as well as the deposit welding on the primary spring seat. It is possible that the combination of these factors, together with the excessively thin bottom plate of the bogie frame, resulted in the crack [1, 2]. A JTSB progress report, released on 28 June 2018, also inferred that the weakening of the bogie frame part (due to the excessive grinding combined with the residual stress from the deposit welding) resulted in a fissure near the welds, triggering the development of a fatigue crack [3].

This case study explains that Shinkansen rolling stock is produced by contracted rolling stock manufacturers and parts suppliers, and operated and maintained by railway companies. This incident reveals a communication gap between the relevant organisations. In contrast, rolling stock design is conducted by multiple organisations but led by railway companies, as explained later. There are complex inter-organisational relations between railway companies and contracted manufacturers. This chapter will examine how railway vehicle safety is shaped within the context of these contract-based inter-organisational relationships and where problems with this process may lie, using an original analytic framework called “the MAIS approach”.

4.2 The MAIS Approach

What is the MAIS approach? It originates from studies on “The Social Shaping of Technology” [4, 5].

“MAIS” is an acronym for “material entities” (M), “actors” (A) and “institutions/structures” (I/S). The MAIS approach is a research approach focusing not only on interactions between actors but also on interactions between actors and material entities or institutions/structures.

The purpose of the MAIS approach is to elucidate the processes of formation, reformation and transformation of human society under the constraints imposed by various material entities, institutions and structures, and to find clues for effective human intervention during these processes. The MAIS approach identifies actors involved in a social phenomenon. Furthermore, it elucidates his/her interactions with other actors or with various material entities and institutions/structures. Actors can be divided into individual and collective actors. They have unique interests, intentions, attributions of meaning, reflexivity and agency. They also attribute meaning to other actors, material entities and institutions/structures. Through their actions, they form, reform or transform other actors, material entities and institutions/structures. However, they are also constrained or reinforced by the actions of other actors, material entities and institutions/structures.

The MAIS approach also identifies material entities (both artificial and naturally occurring). Moreover, it elucidates the interactions among material entities, actors and institutions/structures. Different actors sometimes attribute different meanings to the same material entity. These entities are not only formed socially; they also possess physical properties (mass, energy, material stability, etc.), indicating that they form part of nature. Therefore, regarding material entities, it is also necessary to understand the physical properties involved in various interactions. Although actors attribute meaning to material entities and can control them to a certain degree, occasionally through the use of institutions/structures, they cannot have complete and permanent control over them because of their physical properties. Material entities not only constrain interactions among various actors, material entities and institutions/structures but also enable and facilitate them.

In addition, the MAIS approach identifies institutions/structures that strongly influence social phenomena. The approach clarifies how each institution and structure interacts with other institutions/structures, various actors and material entities. Institutions/structures are socially constructed throughout history. They are patterned social relationships that constrain or reinforce actors within a limited social space and for a certain period. Regarding the distinction between institutions and structures, the former are purposefully designed by certain actors and are often visible, whereas the latter emerge through the interaction of actors and are invisible. However, as this distinction is extremely complicated in practice, I refer to both collectively as institutions/structures. Institutions/structures constrain and promote interactions among other institutions/structures, various material entities and actors. However, they are also constrained or reinforced because of the said interactions. To understand the influence of these institutions/structures, it is necessary to understand the meanings attributed to each of them by various actors and the consequences (including unintended consequences) of their interactions.

Thus, the MAIS approach seeks to reconstruct the formation, reformation and transformation of social phenomena from the interaction of identified actors, material entities and institutions/structures, in order to thoroughly understand the social phenomena. In this case, we have applied the MAIS approach to the institutional system of railway vehicle construction in Japan drawing on data from two published papers [6, 7] and two interviews with individuals working for both railway companies and rolling stock manufacturers in July and August 2018.

4.3 Inter-organisational Relations and Efforts to Shape Railway Vehicle Safety in Japan

Japan's railway vehicles may be designed by railway companies or rolling stock manufacturers. Designs by rolling stock manufacturers can be further categorised into co-designs or one-company designs. Co-design is a process in which responsibility for the design is divided among multiple manufacturers. This is the method adopted

by the Japan Railways Group (JR Group) including JR-West [7]. This chapter focuses on such co-design projects that involve inter-organisational interactions.

In a co-designed project, one or a few JR Group companies first create a system (basic) design of their new train vehicles. For Shinkansen vehicle development, there are cases in which only one JR Group company develops new vehicles as well as cases in which multiple JR Group companies are involved. They host the so-called *benkyokai* (study meetings) on the new train project with several rolling stock manufacturers, almost all of whom have a longstanding relationship with the railway companies. Such long-term inter-organisational relationships are common in Japan [8, 9]. Later, the JR companies assign the detailed design of different vehicles (power cars, passenger carriages, etc.) to each shortlisted manufacturer [6, 7]. The manufacturers are chosen by tender among the members of the *benkyokai*; usually, multiple companies are chosen because of the limited manufacturing capacity of each company and for risk management.

Each rolling stock manufacturer then holds another study meeting with their customers (JR company/ies) and several parts suppliers. Most of these parts suppliers have a longstanding relationship with the rolling stock manufacturer and the JR Group. Thereafter, a parts supplier is chosen as the designer of each component by tender. Such long-term and quasi-hierarchical relationships among suppliers are akin to the so-called *Keiretsu* [8, 9]. The order is placed by the rolling stock manufacturer or directly by JR company/ies. Parts suppliers prefer direct orders from the latter because this allows them to charge higher prices than when receiving an order from the rolling stock manufacturers. However, typically only certain important components, such as a major controller or a bogie, are directly ordered by the JR company/ies.

In this manner, the manufacturing and partial design of the train vehicles is outsourced to multiple rolling stock manufacturers and parts suppliers. Each contracted manufacturer is only responsible for its own part of the design, but when rolling stock is manufactured, the manufacturers must assume responsibility, not only for the elements they designed, but also for the elements designed by other companies. In other words, the outsourcing allotment of design and manufacturing differs [7].

In the railway vehicle development process of the JR group, the railway companies' vehicle design divisions decide on the vehicle concept, which includes its objectives and specifications. They also manage the overall project and reconcile the needs of manufacturers. They organise a *benkyokai* with potential contractors before orders, conduct design review meetings with contracted manufacturers for each allocated section and hold *tsunagi* (integration) meetings with almost all contracted manufacturers to secure the integration of the train's electrical and software systems. The head of such a division at a railway company is often the person in charge (PIC) of a vehicle's development [6, 7].

It should be noted that JR company/ies can collect many ideas about technology and safety from various potential contractors at a *benkyokai*. Manufacturers are so

eager to accumulate a large order that they emphasise their technological excellence. Although manufacturers compete, their different ideas are incorporated into the design of a new train by the meetings [6].

In this manner, railway companies manage the outsourcing of the design and manufacturing of vehicles and parts. They seek to resolve issues, including safety issues, by exchanging information and opinions during preliminary consultations and at the basic planning stage, by holding design review meetings during the design process, and coordinating among external contractors. While long-term business relationships with multiple rolling stock manufacturers and parts suppliers do secure a socially and economically advantageous position for railway companies, these relationships also promote railway vehicle safety via the accumulation of railway-related expertise by the manufacturers and suppliers they outsource to [6]. This is the critical structure of inter-organisational relationships of co-design projects for railway vehicles in Japan.

During the manufacturing stage, collaboration between railway companies, contracted rolling stock manufacturers and parts suppliers continues. However, there is typically less collaboration between different rolling stock manufacturers at the production stage than at the design stage. As an exception, when a manufacturer faces a technical problem in manufacturing, it can consult its rival manufacturer or a parts supplier who has acquired experience or know-how on the matter. This type of relationship is reciprocal. However, at this stage, the relationships between railway companies, rolling stock manufacturers and parts suppliers are predominantly mediated by blueprints. There are few meetings to coordinate the different inter-organisational relationships of railway companies during the manufacturing stage. When manufacturing small and simple products, it is easy to standardise these through blueprints and automatic manufacturing equipment only. However, manufacturing processes for large products, such as railway vehicles and bogies, often require work to be done by hand. In these cases, social mechanisms and actions for the integration of relevant organisations and their workers are indispensable to ensure the safety of each product.

4.4 Analysis

We will now use the MAIS approach to analyse how vehicle safety is shaped in Japan's railway system. This is a complex sociotechnical system involving various inter-organisational relationships.

First, during the design stage, multiple actors (i.e. railway companies, rolling stock manufacturers and parts suppliers) pool their individual resources and knowledge and cooperate within the institution of co-design. This is achieved, even though there are potential conflicts among competing manufacturers, partly because of the structurally overwhelming power of railway companies as the sponsor and partly because train components exist only as symbolic information at this stage. At this stage, a railway company's vehicle design division (or the PIC within it) is an actor

who takes the initiative to reconcile potential conflicts between manufacturers. The official reconciliation institution is the *benkyokai* and the design review meetings. The integration of inter-organisational relations during the design stage is thus achieved, not only by the efforts of the key actor (the JR vehicle design division), but also by institutional/structural factors, such as the power relationships between JR companies and the contractors and *benkyokai*. This is easier at the design stage than at the manufacturing stage because the products of design are symbolic information, which is copiable and free from material constraints of physical train components.

In terms of building safety into vehicle designs, *benkyokai* are used, wherein railway companies exchange information with rolling stock manufacturers and parts suppliers during the initial phase of the design to compile a list of anticipated problems and their solutions; the solutions are then incorporated into the design. The smooth functioning of this institution requires active commitments from all related actors: railway companies, rolling stock manufacturers and parts suppliers. Blueprints and various prototypes may be considered critical material entities, strongly related to incorporating safety into the vehicle design during the design stage. However, material entities only constitute a portion of the mechanisms for integration. They shape the safe design of railway vehicles together with the key actor's effort for integration and institutional settings such as *benkyokai*. Again, the backdrop of this unique collaboration among competing manufacturers is the JR-centric power distribution and JR's sense of responsibility and pride in the safety of the Shinkansen. The strong attitude towards safety of the most powerful actor and lower material constraints during the design stage than during the manufacturing stage seem to be the key for this inter-organisational collaboration for safety.

Collaboration between the actors of railway companies and contractors carries over into the manufacturing stage. However, there are far fewer interactions among relevant actors at the manufacturing stage than at the design stage. During the manufacturing stage, the relationships between rolling stock manufacturers and parts suppliers are mediated by material entities: thus, the rolling stock manufacturers assemble the parts manufactured by the parts suppliers according to the approved blueprints. Similarly, the relationships between rolling stock manufacturers and railway companies are also mediated by material entities, such as the rolling stock and blueprints. We also did not observe institutional devices for integration during the manufacturing stage, as with *benkyokai* in the design stage.

Another point of variance between the design and manufacturing stages is the increased influence of material entities that mass production entails. The institution of standardisation becomes critical when rolling stock, and parts are mass-produced. Standardisation of production processes is needed to ensure the standardisation of rolling stocks and parts. This requires not only the precision of material entities, such as blueprints and machine tools, but also the skill and focus (carefulness and/or mindfulness) of the relevant actors. The actions of workers are influenced by structural and institutional factors, such as the organisational culture of safety, rules and human resource management. It should be noted that this setting for the standardisation of railway vehicle production must be maintained consistently by all the relevant manufacturers of rolling stock and parts. For the safety of railway vehicles, the

communication between relevant organisations should be stronger than dependence only on the material entities, such as blueprints. Institutions for the communication and commitment of relevant actors are also necessary.

In the serious incident described above, a portion of the bogie frame was weakened because the contracted rolling stock manufacturer used an inappropriate method to correct a defective part manufactured by a parts supplier. This happened because the worker responsible did not act in accordance with the standard policy of the production process. The defective part then cracked due to metal fatigue over time. As outlined above, one problem during the manufacturing process can affect the safety of the entire railway system. Shaping this safety requires smooth interaction among many actors (e.g. workers), institutions (e.g. organisational rules and cultures) and material entities (e.g. various structural parts). In this case, the sharing of information among relevant organisations (i.e. the manufacturer of parts, the manufacturer of the bogie and the railway operator who was responsible for the inspection and maintenance) was insufficient. During the manufacturing stage, there is no centralised actor analogous to the design stage's PIC. There is no institution designed to unify the actors analogous to the design stage's *benkyokai* and design review meetings. In addition, to produce a great number of heavy, complicated hardware items, such as railway vehicles and bogies, require a larger, dispersed and diversified inter-organisational setting, which makes coordination much harder than in the design phase.

4.5 Conclusion

Analysis using the MAIS approach revealed that there are actors (the vehicle design divisions of railway companies) and institutions (*benkyokai*, *tsunagi* meeting and design review meetings) in place for the overall safety coordination of the co-design of railway vehicles, but there are no such actors or institutions in place for their co-manufacturing. This is probably because the relevant organisations believe that making parts and vehicles exactly in accordance with the blueprints would achieve the correct results, without requiring further coordination. However, unlike design, manufacturing has to repeatedly mass-produce the exact same parts and vehicles; that is, manufacturing requires standardisation. This cannot be achieved by sharing the same blueprints. The manufacturing of railway vehicles requires handwork. Therefore, standardisation can be achieved not only by blueprints and correct manufacturing equipment but also by intentional and mindful efforts of the employees of contracted manufacturers and railway companies. Institutional devices for promoting actors' efforts are also crucial. When conducting inter-organisational manufacturing, we should create an inter-organisational institution for standardisation to secure product safety. We can increase the safety of railways by such inter-organisational institutions with shared organisational culture for safety, by the relevant actors' increased commitment to the cause and by mobilisation of material entities such as clear blueprints and correct manufacturing equipment during the manufacturing stage as well as inter-organisational coordination during the design stage.

We may be able to apply this to other contracting-based projects related to safety. When we produce a system in an inter-organisational setting, its safety cannot be built simply by material entities but also requires institutions for coordination, and the full commitment, communication and leadership of relevant actors. We should also create structural circumstances for safety and remove any structural factors against safety. We should find how to achieve these conditions practically even in the mass production of large, complicated and potentially dangerous systems with a dispersed and diversified inter-organisational setting. The MAIS approach can be helpful in analysing such a situation and identifying key material entities, actors and institutional and structural factors. However, further case studies of various projects are necessary for the validation of these conclusions.

Acknowledgements This work was supported by JSPS KAKENHI Grant Numbers 15K03567 and 20K01880.

Ethical Statement This work adhered to the research ethics that are stipulated in “For the Sound Development of Science-The Attitude of a Conscientious Scientist” edited by the Japan Society for the Promotion of Science (JSPS). Informed consent was obtained from participants and all data has been anonymised.

References

1. JR West, The Advisory Committee on the Serious Incident of Shinkansen, *Shinkansen ijo kanchi-ji no unten keizoku jisho heno saihatu boushi ni kansuru kento kekka ni tuite—shinkansen no saranaru anzensei koujo ni mukete* [An Examination on the Measures Against the Recurrence of Keeping Shinkansen Running on the Detection of Abnormality—Towards the Improvement of Safety of Shinkansen] (27 March 2018), https://www.westjr.co.jp/press/article/items/180327_00_yuushikishakaigi_2.pdf. Accessed 12 Aug 2018
2. Kawasaki Heavy Industries, *Notice of Series N700 Shinkansen Train Bogie Frames Matter* (News Release, 28 February 2018) http://global.kawasaki.com/news_C3180228-1.pdf. Accessed 12 Aug 2018
3. Japan Transport Safety Board, *Tetusdo jyuudai inshidento chosa no keika houkoku ni tuite* [Interim Report of the Investigation of the Railway Heavy Incident] (28 June 2018), <http://www.mlit.go.jp/jtsb/railway/rep-inci/keika180628.pdf>. Accessed 26 Nov 2018
4. D. MacKenzie, J. Wajcman (eds.), *The Social Shaping of Technology*, 2nd edn. (Open University Press, Buckingham, 1999)
5. R. Williams, D. Edge, The social shaping of technology. *Res. Policy* **25**(6), 865–899 (1996)
6. T. Kitabayashi, Product development management of rolling stock in Japan and its global expansion: case study of T3 project. *J. Japanese Oper. Manage. Strategy* **6**(1), 34–54 (2016)
7. T. Kitabayashi, Collaborative factors among suppliers in multi-sourcing: case study of joint development for rolling stock in Japan. *Nihon Keiei Gakkai-shi* **39**, 3–14 (2017)
8. W.M. Fruin, *The Japanese Enterprise System* (Oxford University Press, Oxford, 1992)
9. T. Nishiguchi, *Strategic Industrial Sourcing: The Japanese Advantage* (Oxford University Press, New York and Oxford, 1994)

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.