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The Key to Development Is "Link"
– What Supported the Development of 2-Coupling Articulated Low-floor LRV –

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If my memory is correct, it was October 1996 when the news "We won New Jersey Transit (NJT)!" broke in our company. With no knowledge of what kind of vehicle was talked about, I first thought, "Oh, is that so …" but little else. At that time, I was in charge of the management of vehicle design, and therefore was not involved at all in the project proposal. Also, as the proposal was prepared mainly by the U.S. affiliate of Kinki Sharyo (KS), I didn't know any details of the vehicle for which we received the order.

Over subsequent several internal meetings to deliberate actions related to the project, a mood formed of itself which cried, "Sugimoto will do it!" I thought, "Now it's got serious, but what kind of vehicle is that, to begin with?" and looked with more attention at a vehicle model drawing attached to the proposal. I was surprised to find, in the drawing, a 3-body (A-C-B) 2-coupling low-floor LRV with which we were utterly unfamiliar. I hurriedly sent a fax message to our U.S. affiliate, reading: "We can't possibly make such a vehicle!" Then, Mr. Norio Hara, the company's president, replied, "Stop grumbling, come here and begin your work!" It was a far too inconsiderate order, but thus began my long struggle to come up with a suitable vehicle design.

According to a record, NTD came into effect on November 1, 1996; and we held a kick-off meeting with NJT in the middle of the month. The meeting was enlivened by a scale model brought in by Mr. Kenji Minai. But I also remember that glancing at a drawing of the model proposed by us, the person responsible for NJT business remarked coldly, "Probably you should go to Europe and study low-floor LRVs there." I wasn't surprised very much to hear this, because I knew that the greatest challenge was the coupling construction. However, I was still groping in the dark to find an approach to overcoming this difficult challenge.

Fortunately, our company had already enjoyed technical cooperation with SIG, a Swiss vehicle manufacturer, regarding the coupling construction for Boston-bound LRVs. Thanks to this relationship, salespeople from SIG still visited us from time to time to exchange information. I thought that the best thing to do was to seek cooperation from SIG again, and flew to Switzerland right after the end of New Year holidays. My team consisted of four people, including Mr. Masakazu Sakurai who made a detour to Switzerland on his way to Cairo. He represented a trustworthy supporter, as he had maintained contact with SIG after the Boston LRV project, and had a deep insight into the design of this kind of vehicles. Mr. Rainer Hombach from KS's U.S. affiliate joined our team. Together with two other people (Mr. Kozo Ueta and Mr. Genshiro Komeda), our team made a detailed discussion with SIG. However, SIG found it impossible to come up with a measure that could be adopted immediately. The only hint we got from the meeting was an observation that there were some vehicles using a rooftop link.

The greatest challenge with the vehicle was how to stabilize the middle body (C body) supported on the bogie with bolster springs. However, we had to take some more time to reach a concrete solution.

In Switzerland, I parted from Mr. Hombach and Mr. Ueta who were to visit a European parts manufacturer, Mr. Sakurai heading for Cairo, and Mr. Komeda returning home; and flew to Boston where KS's U.S. affiliate was located, to make the first discussion with the manufacturers of propulsion and brakes, which represent basic vehicle systems. It was anybody's guess that the fortunate selection of a propulsion manufacturer at that time would later contribute greatly to facilitating the development of an electric bogie for low-floor vehicle, which meant another great challenge. Our intention immediately before the meeting was to use a Japanese propulsion manufacturer. At the meeting, however, it was decided to use Alstom based on a comprehensive review of technical proposals etc. Thanks to the cooperation of highly competent engineers from Alstom and Voith, we eventually succeeded in completing the design of an electric bogie equipped with a hollow-shafted double-reduction drive.

After the meeting, we repeatedly held technical discussions first with Alstom, then with Knorr (a brake manufacturer) and with other system manufacturers to reach PDR and FDR. We reached FDR toward the end of October 1997, about one year after NTP. This remarkable progress in design could be achieved thanks to a combination of efforts and sheer lucks. First, we could prevent the customer or its consultants from making excessive demands, because in the project, which was our first DBOM project in the U.S., we, as the contractor, were to take charge not only of manufacture, but also of operation and maintenance. Also, the responsible person from the customer made correct judgments and timely decisions; in response, our engineers to do their utmost, including Mr. Jun Kashima who put everything he had into the design of an energy-absorbing body structure. In addition, Mr.

Hombach, as the project manager, resided in New Jersey to maintain daily contacts with the customer.

Now, I will return to the subject of coupling structure. After giving us a hint at rooftop link, SIG, upon our request, sent us a copy of a magazine article showing a vehicle side; and a proposal for a structure for linkage between A and C bodies and between C and B bodies, which resembled the crank mechanism of a motor vehicle. Though I understood that this mechanism was all right in terms of sheer function, installing it on the roof seemed absolutely impossible. After much deliberation, I arrived at a Z-link mechanism involving the installation of a swing bearing on the roof of the middle (C) body. I hastily prepared a sketch of this structure; estimated the external force working on the structure in operation; and phoned a bearing manufacturer with which Mr. Victor Amurgis, the person responsible for materials in the U.S. affiliate, had begun negotiations, to request an examination of the type and size of the swing bearing. I had to do everything at once to be on schedule.

The next challenge was to see that the LRV with this structure ran stably at 55 mph (88 km/h), the specified maximum operating speed. At that time, we didn't have any general-purpose software that could analyze the movement of a vehicle of such a complex design. Even if we could have managed to buy one, we'd had no time to train engineers to use it. When I consulted SIG about this matter, it replied that it had some software resembling ADAMS, which could analyze multi-body dynamics. ADAMS is a piece of software for motion analysis, which had begun to be used at the Railway Technical Research Institute and other organizations. I desperately asked SIG to send me a data input sheet, filled it out with an enormous amount of input data, and sent back to SIG for calculation.

However, the answer I got was that the design could not prevent vehicle yawing. I checked for data errors and asked for re-calculation, but I got the same result. A natural step in such a case is to install yaw dampers additionally between bodies, but at that time it was difficult to locate dampers at an appropriate position, as the design of the rooftop and the section between bodies had progressed to a considerable extent. After several failed attempts, I came up with a design involving the installation of two dampers on the roof, with the body centerline in-between. The answer was "Congratulations!" – which meant that I succeeded in controlling yawing.

Subsequent detailed analysis proved that the external force, working on the link mechanism during passage of a minimum vertical curve of 250 mR, was not significantly different from an estimated value; and that there were no problems with the performance of the bogie (which was installed below the middle [C] body and could not rotate) regarding passage of a specified minimum horizontal curve of 18 mR. I frequently discussed the vehicle design with SIG, as we had entrusted the company with the design and manufacture of the middle bogie with independent wheels. On these occasions, I was impressed with the excellent abilities, instinct and methodology of SIG's engineers, and learned much from them. In connection with the bogie design and the above-mentioned analysis for vehicle design, I sent an enormous amount of fax messages to SIG engineers and the project manager, and received as much from them. I stored files containing these messages in the bottom of a corrugated carton. People sometimes ask me, "Why are dampers on the roof located at asymmetrical positions relative to the vehicle center line?" I assume that readers can easily find a key to this question from what I told before.

Two prototype vehicles were completed in October 1998, and FAI (First Article Inspection) was conducted by installing a makeshift platform on our company's test track, with the attendance of many guests from NJT. Among people who were experiencing the comfort of a trip aboard a low-floor LRV, probably no one noticed a man running on the track after the vehicle, seemingly listening at something. That guy was me: Please understand – someone who has just created a new vehicle can become so worrisome.