

BUILDING SINGAPORE’S MASS RAPID TRANSIT SYSTEM-SOME SYSTEMIC LESSONS

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Abstract: The aim of this paper is to capture some useful lessons in the development of the mass rapid transit system in Singapore. A systemic perspective is adopted to view and frame the lessons learned from the multi-phase development. The infrastructural development project can be viewed as a large-scale living human activity-based system that is built to meet economic and societal needs. A set of interviews were conducted to further capture lessons in the construction project management addressing the issues and constraints pertaining to the construction industry in Singapore; and the use and value of a systems approach. The systemic perspective provides a useful mental frame of reference to structure, understand and appreciate the nature and characteristics of major infrastructure development, its planning processes, and the key success factors.

Keywords: Mass rapid transit system; Singapore; construction project management

1 Introduction

This paper aims at capturing some of the lessons learned from Singapore’s experience in planning and building her mass rapid transit network over the past twenty-five years. Firstly, the pre-project study and planning period was particularly protracted and arduous which was reflected upon as Singapore’s Great MRT (Mass Rapid Transit) Debate. The planning, learning and decision process is systemic in nature as it involves both logic and politics. The critical issue was about doing the right thing at the right time, that a mass transit system will provide the long term solution to solve Singapore land transport challenges. The main story of the MRT development is based on Singapore’s Land Transport Authority (LTA)’s documented *Journey to a world class land transport system*.

Further lessons will be learned about the context and process of the construction project management addressing issues related to the challenges facing Singapore’s construction industry, the use and contribution of foreign expertise and labour, and other macro level critical success factors. These lessons will be made self-evident from an excerpt of a series of interviews with the senior project managers with LTA’s Rail Group.

The relevant accounts from the study and interviews will be interpreted and framed basing on a systemic perspective (Yeo 1993, Yeo 1997)) in order to gain a better understanding of the lessons learned about major infrastructure development in general and Singapore in particular.

2 The Singapore MRT Development

2.1 The Perceived Challenges and Needs

By the early 1970s, the person-to-car ownership was still 1:16, but the Singapore transport planners knew the number of car ownership will increase with economic growth, and to keep building more roads was not the answer, as the city state has acute land shortage and cannot build more new road networks. It is estimated that land usage for roads will take up 16% of Singapore’s 685 sq. km land space and reach its limits in the 21st century. (LTA 2004)

As far as the 1970s, there was already a perceived need to restrain private car ownership as a continual large-scale road building scheme would not be sustainable. While restraining private car ownership, it is necessary to build better public land transport infrastructure. The idea of building and using tunnels for land transportation surfaced at that stage. Singapore needed a comprehensive public transportation and traffic management system.

2.2 Articulating the Way Ahead: The Great MRT Debate

The question was then: what could form the real backbone of Singapore's land transport system. Would it be the all-bus system or a high-tech train-based mass rapid transit system, or a combination of both? A Singapore study team was set up in mid-1970s, to work closely with foreign consultants with funding from United Nations Development Programme (UNDP) and the World Bank. Initially, the World Bank was not in favor of the rail idea and asked for further sensitivity analysis on various risk factors.

It took ten years of debates and feasibility studies of different options. This demonstrates the usually long and arduous pre-project planning processes involved to reach a final commitment to a critical infrastructure development. Over this prolonged ideas and definition period, there is a converging view that for the 21st century land transportation, it would be an integrated bus and rail system, with the bus services feeding into a mass transit rail as the backbone of the city-wide transport system.

2.3 The Commitment to Go Ahead

Singapore government gave its final approval for a MRT system in May 1982. The MRT was perceived to be much more than a transport investment, and viewed in its wider economic perspective in terms of gaining foreign investors' confidence, the multiplier and spin-off effects such as added value to adjacent real estate and in promoting economic and social activities. The MRT project was then budgeted at S\$5 billion with a planned completion of an initial 67 km system with 42 stations, by 1992. It was suggested that the project be delayed in anticipation of a worldwide recession to take advantage of lower cost of construction. This was strategic decision which contributed to apparently the lowest per kilometer unit cost of the MRT system ever constructed worldwide.

3 The Living System: The Multi-stage Development

3.1 The First Phases: North-South and East-West Lines

The initial phases comprises of the North-South and East-West Lines. Priority was given to the North-South line because the alignment of the line passed through Orchard Road and the Central Business District (CBD). The first line was operational in November 1987.

The MRT project sponsor tried to keep construction costs down by building the majority of the lines above ground, with only about 25% of the system underground through the CBD areas; as tunneling would always represents the most expensive component of a MRT project.

The Phase I project was a success as it was completed two years ahead of schedule and below budget. Foreign currency exchange risks were well managed with excellent deals on US\$ contracts, protecting the project against foreign exchange fluctuation risk. The project execution is one of technical excellence and courage, especially in tunneling through the CBD areas. The senior project management had been very safety conscious in the process as underground work can be hazardous.

The system functioned well from the start, and has a positive impact on the social fabric in Singapore. The rail network has influenced land use planning, general economic growth and population movement to less developed housing estates and enhances property values along the lines and nearby stations. With the positive response from the commuting public, further northern extension was initiated and completed in 1996.

3.2 The North East Line (NEL) (*see figure 1*)

The Government had foreseen the benefits of the rail system and the need for expansion to serve the North Eastern part of the Island where four new towns would be developed to cater for 0.5 million after 2000. But there was concern that the new line's economic viability in terms of rider-ship and the huge cost of building as the entire line will be constructed underground. Nonetheless, in 1996, the Government gave its approval to the build the NEL, knowing the need to always build slightly ahead of demand and take on some financial risks.



Figure 1: Map of the Northeast Line (NEL) and Circle Line (CCL) in Singapore

3.3 Circle Line (CCL) (see figure 1)

CCL represents the latest development phase of the MRT network to enhance system connectivity. A “spider web” type of orbital network would be built, with connecting radial lines. The building of phase I of CCL commenced in 1999. The estimated total cost of the entire CCL development is S\$6.66 billion. CCL is a 33-km, 29-station orbital line linking almost all the MRT lines running into the city, and the entire project is scheduled for completion by 2010. It runs through the city centre, housing estates, industrial estates, and research institutes and to the harbor front. The CCL will serve the new 372-hectare Marina downtown that promises to be Singapore’s keynote 21st century development.

There will be interchanges connecting at various points with the MRT’s North-South Line, East-West Line and North-East Line (NEL). The CCL will allow commuters to move from suburb to suburb bypassing the city centre, substantially cutting travel time. Each of these stations will have their own personality as expressed through artistic design features. For instances, the Museum Station will have a glass-bottom reflection pool that shafts sunlight into the underground station; and Promenade Station will also feature skylights with a view of the surrounding skyscrapers. The dominance of the MRT, the backbone of Singapore’s public transport system will be inevitable. Further MRT investments to 2030 are slated to cost a further S\$21 billion. (LTA 2004)

4 Some Lessons in Construction Management

4.1 Growing Maturity

In 1983, the MRT Corporation (MRTC) project organization was set up to be the developer and future operator of the proposed rail systems. MRTC built up its core team quickly with the supports of expatriate consultants recruited from Hong Kong and UK. At the peak, there were more than 300 expatriate engineers working under MRTC. According to LTA, these expatriates were expensive but very professional, and also

difficult to manage. However, these expatriates were experienced and strong-minded, with many of them from Hong Kong rapid transit project, and who tended to expressing themselves freely, and getting their own way. (LTA 2004)

Today, the number of expatriates with the Land Transport Authority, LTA (incorporated MRT) working on rapid rail systems has dropped to around forty. There is growing maturity in building rapid rail systems in Singapore gained from almost 25 years of developmental experience with excellent track record.

The following sections are extracts from a series of interviews with project directors and senior project managers in LTA who have witnessed the growing maturity in the planning, designing and building Singapore's mass rapid transit system since the 1980s. The interviews and the site visits on Circle Line construction also provide glimpses of the current practices in construction project management and construction industry in Singapore.

4.2 Interviews with LTA's Senior Project Management

The interview was conducted in January 2006 at LTA, by the authors. The interviews were conducted with a range of senior project managers comprised of expatriate and Singaporean senior project managers. The interview question and answer sessions were tape-recorded and transcribed. The following section gives a condensed version of the interviews extracted to highlight major lessons learned. The earlier sections 2 and 3 provide the background and context to appreciate the Q & A interactions.

(a) On capability of the construction industry:

Western authors and researchers have been writing about non-Japanese Asian companies that lag behind in capability in designing, developing and delivering complex system projects to the Western countries in the US and EU. The developing Asian economies are still the recipients of Western engineering-intensive systems. The following questions begin by finding out the perception of construction management capability in the Singapore and Asian context. The interview also dwells on issues related to systems applications, constraints in project leaderships, the roles of expatriate project managers and experts, and availability of skilled labour pool in the construction industry in the Singapore context.

Q: Singapore's local construction industry is believed to be several decades behind that of Japan. From this MRT (mass rapid transit) construction experience, how do you find construction capability here in recent years? It is also noticed that most mega projects seem to be directed by Western project managers and the inputs from Western expertise is quite high. Are Asian project managers not up to the challenge?

A: In terms of quality of work and schedule, we are just as competent. We import technology, expertise and methodology of managing projects from Japan and Western countries. MRT was one of the first few in the world who started out with the Design and Build (D&B) Approach. In terms of contract management, we done quite well as past records showed projects being completed on time, within budget. We have (built) very good E&M (electrical and mechanical) systems. One success story is the story of the North-East Line (NEL) that LTA was able to build the world first heavy weight driverless metro system. In terms of quality, I know the Japanese work the conventional way even though others may have moved forward. They stick to the same method because it is safe and there is proven track record.

Q: Let's say there is a contract in the Europe, would Singaporean contractors bid for these major projects?

A: Asia (owner sponsors) today has money and human resource to do major projects. For example, Hong Kong may be the owner or developer, but initially not the one which provided the skills to actually build it (the mega infrastructure projects). Comparing the skills of local and HK contractors, Singapore contractors still lack financial stability and skills. Singapore is equipped with management skills, including advanced management skills but lack the 'muscle' (e.g. critical mass of human talents) to support the skills. They still need external professionals to help them. They are improving, in terms of skills and experience.

In that point of view, Japanese contractors and Singaporean contractors are in different leagues. Japan has contractors that are enormous, such as Nishimatsu (which has been involved in several phases of MRT construction). Not many European contractors and just one or two in the U.S. can compare to Japan's Nishimatsu. They are also quite diverse in their work. They don't focus on one element of work and have a

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whole range from low-cost housing to bridges to dams and they had the that experience from projects all over the world over a long period of time. It would be an exception to see a Singapore (contractor's) project manager leading a project in Europe. This is an exception because many of these project managers come with background of being just under a construction contract (hence not having the whole life cycle experience). While, Nishimatsu projects in Europe will have Japanese senior management onsite instead of local European senior managers.

In Singapore, the government gives local companies many opportunities for contracts, but many Singaporean contractors have ‘weak’ mindset that they are not getting enough supports and opportunities from the government. They tend not wanting to hire (high-salaried) professionals to help and manage projects like family-based style.

Q: In manufacturing, Acer's Stan Shih (former group chairman) came up with the idea of a smiley curve, with light-hand side on high-tech development (product and process), left-hand side on supply chain and professional services, while the bottom is the assembly operations which are now outsourced to low cost suppliers. On the same token, can Singapore forget about local contractors and just rely on and sub-contract to foreign contractors (e.g. China Construct?)

A: A few success cases of Singaporean contractors who have done well are Sembcorp, (a Government-linked company), and Lam Chang in the MRT projects. Lam Chang always tie up with Nishimatsu. They diversify out of construction and are involving in real estate and other businesses. Due to small profit margin (and competition) in construction, they tend to take many small contracts. They do a few different types of projects as they cannot survive on only one type.

Q: So what would be the future here for Asian construction industry in overseas market?

A: There's one element not yet touched on. That's the rules and regulations or safety requirements. There was a case of a (foreign) contractor who was unfamiliar with the European state laws and the client was very worried to run foul of the laws. For Singapore contractors, unless they know and familiar with these regulations (in a foreign country), they will not be able to work on tunneling. It is not only about knowing the methods to do it, it must be demonstrate that the company can do it.

(b) On Systems capability & applications:

Q: Looking at the whole issue of capability maturity. To take it broadly, one is at the human level and another at the systems level. How much do you emphasize for all these years (in MRT construction), the importance of systems applications (system procedures and assisted by software tools)? How did giant American construction firms like Bethel do it? On the other hand, many Japanese firms are also able to achieve good performance yet, depend less on systems?

A: Experience in Bethel is that they are completely and utterly (systems) procedural driven. All that needs to be done are all defined through this system.

Basically, the complex nature of projects in LTA is mainly in the interface between civil and E&M works. The civil work on its own is actually not that complex. Our top civil guy prefers to use bar charts on the wall. But it comes from the software system. If you have a good appreciation of the job, and you understand where the difficulties are, and you focus on the difficult areas then that's probably what you need to do. The key is knowing what you are doing.

For a large MRT project, bar charting is not good enough. The variables keep changing everyday on the construction site, so we need to take notice of that and update. The bar chart is fixed and we revised the bar chart to know where we are. So, this is where the software applications are used. In LTA, we use Primavera (commonly used in the construction industry). The straight forward answer to your question is that it is essential nowadays, in terms of system software and procedures.

Q: Do you genuinely believe in it (computerized systems approach) or is it some contractual requirements?

A: Yes, without doubt. Speaking in terms of modern project management, we've got a duty to report upwards. To report upwards not only the facts and figures, senior management also got to know where we are, down the road of what will be the impact in the future. Contractors produce programme and schedule and LTA personnel monitor them based on the guidelines given by LTA.

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Well, speaking about the use of systems (approach), what I found in the NEL project is in E& M works. As project manager, you look after the defined set of contracts because it's not practical for you to look after the whole load of work, so you define an area of work. You'll use a fairly extensive programme to help you monitor the project information. So there's a lot of information that can still be misleading unless you question the information that's coming in, get a chart that allows you to question the contractor on his progress. A delay may be detected and quickly recovered due to actions taken. Keep a check and balance.

The importance is that everyone (client and contractors) must use a common basis (such as systems and criteria) to support the programme. And that has to be cascaded upwards to senior management for an overall review so you can see who is slowing down/delaying (progress). They are coming together at different works. Strategy for programme management is coordination so everyone can start work and hopefully to finish on time. Award contracts at time when they are needed. For example, there is no need to award contract for (train ticket) fare-collectors at the beginning. For NEL, there are about 40 main contractors and slightly less than 100 minor contractors.

But if civil works do not finish on time to receive the trains delivery then you have a big problem, it doesn't matter whose the problem is. There needs to be a high level overview. So you can see if your delivery of trains is going to be early or late. In fact early delivery doesn't always mean a good thing. It needs to be managed for all your programmes to come together (in timely manner). Eventually you still have a very big reliance on systems.

Q: Do you dictate a common reporting format for all contractors?

A: Yes, it has to be. LTA gives reporting requirements, a contract obligation.

Q: Are they reporting to manual form or key-in through a database?

A: They key-in on their own systems, and then pass a CD to LTA. They have not yet used an internet-linked system, due to broadband and firewall constraints at the moment. We have been looking for an integrated project management system for many years. Now, there are other issues like security problems to deal with. But we are sure it (an internet based integrated project management system) will happen.

Q: For Circle Line (the latest and ongoing), is there a center for visibility of plan/ progress?

A: Not for public view. LTA's Programme Planning Office is considered the nerve center. We managed it manually. What happens is that the project progress reports are channeled through the Programme Planning Office, and then planners will collate the information and report upwards along with monthly progress reports. Trend charts are produced at individual levels (and contract areas). We have trend charts produced on site level, tracking every site action and progress, what is the trend of construction activity, and whether it is on schedule or delayed. At a higher level of reporting, it'll be a combined reporting for management to see the overall picture with graphics.

(c) On Project risk management: Dealing with weak-link:

Q: The Critical chain project management, CCPM, (Eli Goldratt, 1998) suggests that we give focus to the major critical constraint or the weak-link and overcome it one at a time. How is your MRT experience?

A: One of the difficulties in project management is dealing with software development (for signaling and control). It is more difficult to establish firm timelines or get confident with success. It needs to put all systems together and then you'll see how successful the software is, especially when applying new software even if they are pre-tested overseas. There is significant level of project risk in software. Trains will not run unless the (software-enabled) signals are correct for them to work.

Software is a critical item. For the NEL development, the S\$5 billion project could be at risk due to a S\$20 million contract of software developed in France for signaling. Jubilee line (in London Underground network) reverted to a basic software arrangement from the one they were developing for automatic rail control, due to the high risk involved.

Q: A \$5 billion project with all physical infrastructures completed, but the \$20 million software is faulty. There is lesson to be learned about project risk management!

A: The systems approach tends not to take risk, and it is good for the conventional system. Never take risks; you never have a new system (e.g. driverless trains, better software). For NEL, management approaches the project with an open mind. We identified risks and we think we have the capability to manage it. Software

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developer overseas has to take staged demonstrations to ensure success for NEL, with pre-delivery tests in advance.

Early appointment of software contractor was one of the items taken to minimize the risk of project schedule overrun. It's better to have the software ready early so that further scope can be defined before the trains' delivery. For NEL, management took a risk mitigation measure to do integration of trains and control system at vendor's factory in Valencia, France. A lot was done in signaling and supervisory control tests since they are high risk areas. We spent money and took additional measures to reduce the risks on signaling.

Q: One way is to ensure a good track record of the contractor?

A: You may be pushing the boundary because sometimes, even contractors do it the first time. Our management is very productive, they identify the issues and problems, and they go in straight away to resolve them. If there is a need to pay, then pay to get it done. Some of the project managers with experience in Jubilee Line (London) are helping problems solving in LTA. They have been involved in problems solving in similar projects, so now they have experience and know where to focus on the problems.

Q: In running infrastructure of this nature, is this kind of prior experience essential?

A: Yes.

(d) On the role of expatriate managers:

Q: How many percent, when an expatriate project manager step in, that he knows what he knows and how many percent, he doesn't know?

A: He'll have to know 90% or more (the predictable risk). But different environment and people issues are the unknowns (the unpredictable risk). In technical matters, he must know (grasp) 90% at least. For human relations, he has to learn on the job. The project setting is different, the environment and organization are different, and rules and regulations may also be different. Foreign experts may make fairly big influences in how technically you solve problems.

(e) On the reliance on foreign labour:

Q: What would be the other major problems?

A: In Singapore, the manpower limitations of the contractors are a major problem mainly due to the lack of very basic core skills among the construction labour, who are mainly foreign (from other developing Asian countries). It seems that once the workers are trained up with skills and soon they got to leave. The Japanese contractors in Japan use Japanese workforce who grow up in Japan, speak Japanese. But in Singapore, the senior management in contracting firms is struggling with workforce from Bangladesh, Mumbai, Thailand etc, with different languages. We got to train them up to do something sophisticated work and after a few years, these people have to go back. And new ones will be brought in and the cycle repeats itself. Singapore labour laws prevent foreign workers from staying in Singapore for too long.

Q: When Japanese contractors go to Europe, do they bring the whole workforce along with them?

A: They use European workers. Japanese project managers, since they have been in Europe for 10 to 15 years, they have a lot of company knowledge and are quite familiar with the local regulations. But in Singapore, the senior project management in a major Japanese construction firm is Japanese, but lower level workers are from India, Thailand, and Mumbai. It could be difficult to get the message of quality and safety to these people.

Q: These workers are employed in turn by the local contractors?

A: Yes. These workers are employed by local Singaporean contractors. The contractors are not allowed to keep even experienced workers here for long. It's a Ministry of Manpower (MOM) ruling. It is difficult to attract local people to work in the construction industry, and to have a sense of loyalty. It is very different in Japan where employees work almost whole life in the same company which looks after their interests. Actually, in the West, they would rather pay for skilled workers.

(f) On keeping good contractors:

Q: Any other challenges?

One problem we face is the difficulty getting good contractors and keeping them. I'm referring to both local and foreign contractors. We don't have continuous flow of jobs for these contractors. So though we get back the same companies, the personnel we have the last time may have left or gone on to another project. Also there's the cash-flow problem for local contractors that can be a concern.

Q: In the long run, local contractors will disappear and the international....

A: No, no! The local contractors' job contents are rather high, except maybe tunneling which still has no local company. Comfort for local contractors is that the client (LTA) will not go bankrupt.

(g) On stable source of funding:

Q: We stated earlier that one of the problems is the limit of a stable pool of reliable workforce. Besides that, what other factors are affecting large projects like these mass transit projects?

A: A stable source of funding is one. Money is in good control. Good government support. The money is released in a more simplified way but still under tight control. Stable single source of funding is conducive. Overseas projects are equity funded so there may be higher risk of loss and interruption of project financing. In developing countries, there is also the political risk of unrest. But in Singapore, a stable government, and a strong steering committee of project sponsors and project management are key factors.

Q: All in all, how do you rate Singapore's transport infrastructure in terms of project performance and the way it has been done?

A: For NEL, A+ and MRT Phase I also A+. So far, all these projects are completed within schedule and budget. Considering the challenges, both projects are very successful. Taipei mass rapid transit project were hindered by political unrest in the end, and took 8 to 10 years to complete. Timing was very good for Phase I because experts were hired from Hong Kong soon after the completion of their metro system. You cannot directly compare NEL with Phase I MRT because as you get more mature, you'll bring in more regulations, more expectations for the subsequent phases.

Q: Can you capture some of the key success factors?

A: The main key success factors are:

- Decision making process at the executive level is quick and firm, convergent, and it cuts out all unnecessary debates.
- Powerful legislation (LTA Act of Parliament)
- More straightforward funding (Single source from MOF-Ministry of Finance)
- Leverage on expatriates' or international expertise.
- Very rigorous risk planning and mitigation. In tender documents, LTA specifies guidelines to reduce or mitigate risks. Engineering and technical risks are analyzed with reference to operational and safety risks.

Q: What are the other risks mitigation measures?

A: We try to reduce the risk of financial collapse of contractors by pre-qualifying them to meet certain financial criteria as well as the availability of skills and expertise of project teams. One other challenge is that we have to deal with other government statutory boards and authorities such as HDB (Housing Development Board), URA (Urban Renewal Authority). In Phase I, there was not that much built housing on land on the routes.

Q: What about exporting LTA's core competence in design and build rapid transit systems?

A: LTA is now bidding in for land transport projects in Thailand, China and Middle East. We are also exporting our project management expertise overseas.

5 Reflection from a Systemic Perspective

A major infrastructure development project such as the mass rapid transit system can be viewed as a large-scale complex human activity-based system. This is a living system that undergoes a divergent-convergent development life cycle with a protracted pre-project feasibility study and planning phase. The pre-project definition and planning is initially divergent in nature focusing on clarifying the strategic intent, concept definition and front-engineering and planning which lead to the final commitment and approval of the project. A soft systems methodology (SSM) (Checkland 1983) would be appropriate to conduct systemic enquiry in

developing a viable mental model as the basis for comparison with the real world needs and situation, and to ensure the intended project and associated change are both technically and socially feasible and desirable.

Upon project approval, project implementation phase follows and aims at achieving rapid convergence to results. The project implementation phase takes a strong systems engineering approach to ensure control and discipline. For systems design, the infrastructure development is viewed as a human activity system to serve both economic and social needs. The MRT system follows a multi-phase development which grows organically as the external environment allows and encourages it.

The practice of project implementation traditionally takes on a hard and disciplined systems engineering approach. The systems approach requires the setting of clear and credible objectives and scope of work. Systems engineering takes on a hard goal-seeking and end-item accomplishment stance. The systems approach place great emphasis on compliance on systems management policies and procedures through effective and stringent requirements on communication and feedback control. The single-minded mission of the program director and his talented project team is to ensure rapid convergence to the pre-determined project goals of on-time, within budget and satisfying the technical specifications.

6 Conclusions

For sustained economic development, nations must invest continually in infrastructure construction. The infrastructure development is seldom a one-off investment. Country planners should take a systemic view of infrastructural development as living human-activity-centered systems capable of continual growth (and decay if neglected), and in need for rejuvenation. Contingency and provisions should be made for future expansion in step with economic progress. Singapore has over four decades of experience and achievements in intensive infrastructure construction. Some of these experiences and lessons learned are universal and some are relatively unique in Singapore's context. In the national development, the construction industry as a whole has made significant contributions as active participant in infrastructure development. The local construction industry should continue to learn from the world class best practices and to leverage on international talents and resources.

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