How Digital Engineering Will Change The Way We Work Together To Design And Deliver Projects

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ABSTRACT

Our industry is witnessing its biggest change since CAD was introduced to our workflows. The Digital Engineering process and all it encompasses is shifting the focus from hand sketches, 2D CAD detailing and red pen to an all engrossing and sometimes daunting 3D, 4D and 5D digital world.

This presentation, from the perspective of the design team, will give an insight into how we can benefit from making the 3D model the central collaborative focus point on small bridge projects while also showing how that same model and its intelligent data can be reused by other disciplines, the construction team and the asset owner. As we know, there are increased financial and time pressures on projects in today's climate, forcing our teams to work smaller, smarter and more efficiently together than ever before. The development of an intelligent bridge model can influence design, increase drawing accuracy, reduce human error and identify clashes before site while also including contingency for design changes with minimal rework.

INTRODUCTION

There is no doubting that Digital Engineering has been the biggest buzz word across the Civil Infrastructure industry for some time now. Our design teams are more frequently required to deliver projects with a BIM deliverable (Building Information Model, more on that later), with many of us not aware of what this entirely means. As designers in these ever evolving digital times, we are witnessing the biggest change since CAD was introduced. The term 'Digital Engineering' encompasses more than simply handing over a BIM at the end of a project, we are able to incorporate digital processes in all aspects of our roles as bridge designers. This paper will outline how as designers we can benefit from setting our own internal Digital Engineering goals, achieving them and by doing so improving many outcomes for ourselves and other project stakeholders.

The way we design, deliver and manage projects is changing with the advancement of technology. There is a statistic that the Construction industry, when it comes to digitisation and investment in digitisation is one of the worst performing sectors, down the bottom of the list with Agriculture and hunting, see figure 1.0. We have a multitude of current and emerging technologies available to help us work smarter together, there needs to be an increased focus on digital investment to really see these technologies shape our industry. Digital Engineering as a whole, has the ability to revitalise the way that we would traditionally design, deliver and manage projects across their lifecycle.

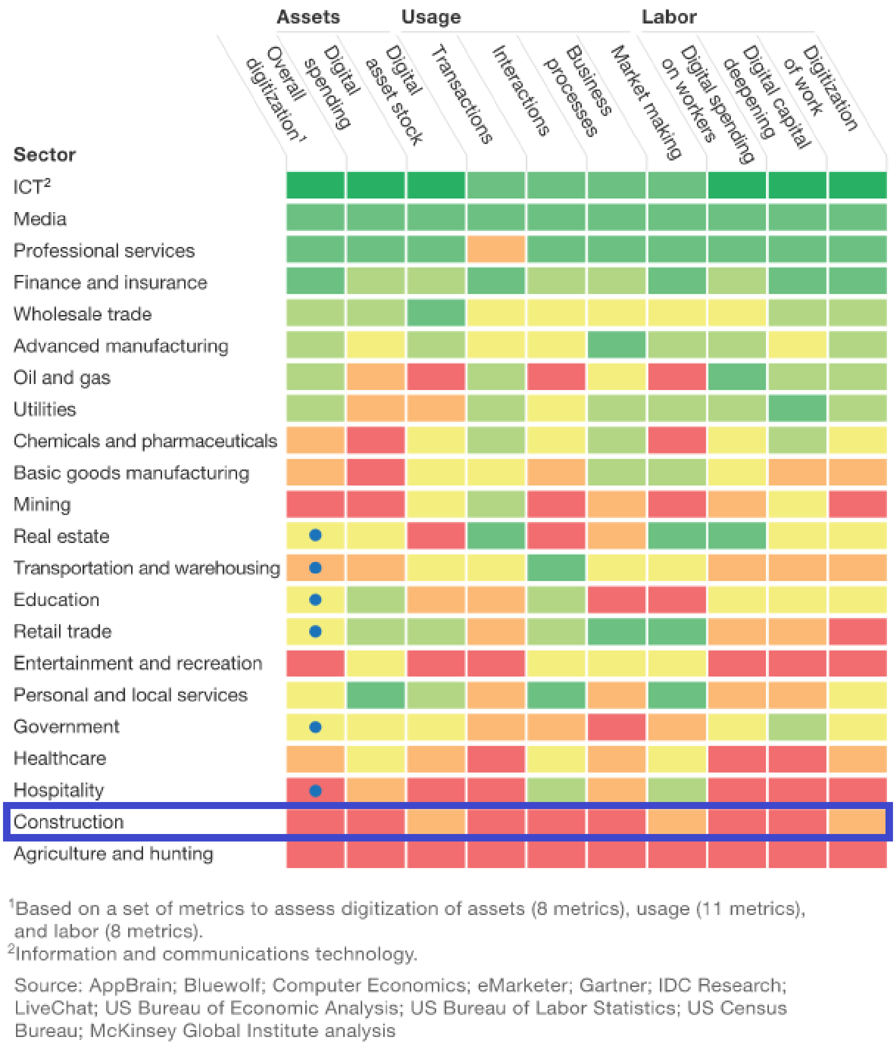

Figure 1.0

BODY OF PAPER

We have at our fingertips, the ability to utilise current technologies to improve the way our design teams work together. The process around this is known as BIM. BIM stands for Building Information Modelling. In short, ‘Building’ refers to anything that we can construct. ‘Information’ refers to the data that we can input into the project and ‘Modelling’ refers to the way that all the project data is managed and contained - inside an accurate digital 3D model that represents the exact dimensions of the proposed built asset. Worth noting, the ‘I’ is one of the most important factors that supports and drives BIM as a whole. The data and information that we can input in the model plays a crucial role in the overall usefulness of the model. BIM is a process and for the project owner, asset manager, designers and construction teams to really see the benefits of adopting this process on a project all of these stakeholders must be on board. In Australia, we are seeing a gradual change and increased adoption of BIM however it may be some time before we can confidently say we are delivering complete BIM projects.

As designers, we can see the benefits of adopting internal BIM processes by setting and ultimately achieving our own Digital Engineering goals. Technology plays a great role in doing this, although it is not the only driver. A change in mindset is required across the board to ‘think Digital’. This paper will show how as a team of bridge designers we can work smarter and more efficiently by sharing digital design data across different software platforms, using this data to update the digital ‘single point of truth’ model which results in more detailed information, accurate drawings, ultimately resulting in time saved and less errors.

At BG&E Autodesk Revit is our software of choice when it comes to being the ‘single point of truth’ model. People will tell you that Revit cannot do certain things, especially with bridges, but with some technical knowhow it is a great tool. The Revit model can be thought of as one big database containing information about the bridge. Data about individual bridge elements can be easily associated to the modelled elements (see Figure 2.0), scheduled, quantified and manipulated to present us with detailed information. The data can be sent to other design software for analysis, brought back in and updated in the model accordingly. The non-Revit users in our team are able to use software to view the model, check its geometries, validate the data and communicate any necessary design changes – without having to see a drawing. This process requires our team to change the way they work, to focus our attention on the 3D model as the central point of communication, which can be a challenge in itself however we have seen the results in our team when we implement these processes successfully. Traditional workflows would see a range of project information scattered across hand sketches, project servers, reports and email inboxes. Bringing all of the project information into a centralised location improves the communication flow and with the introduction of cloud technologies this has also allowed our team to work just as effectively from remote locations or other offices.

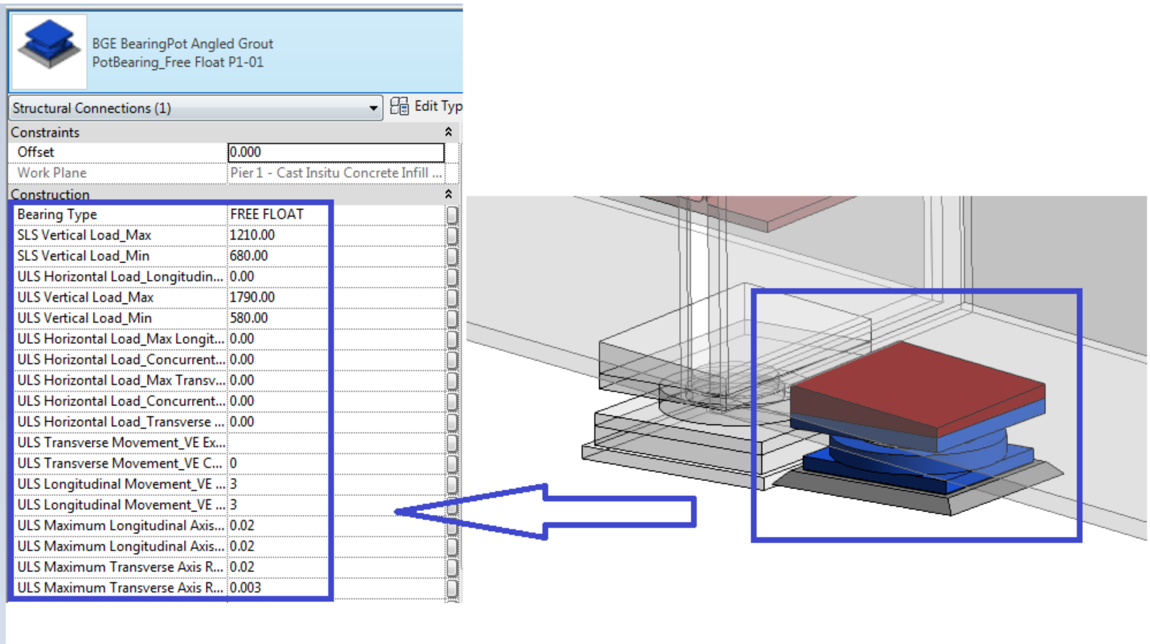

Figure 2.0. Bridge bearing data contained inside the model.

A simple example shown below is our process for the design of Piles. Our piles are modelled under the abutments and piers, a unique mark is associated to each pile, AA-01, AA-02 etc. Schedules with empty fields of data are generated inside of Revit and can be placed on a sheet awaiting the input from someone else. We can then export the pile information to excel and send it to our designer. The designer can now populate all of the design data in excel, including pile lengths, diameters, reinforcement, loadings, the list goes on. Once complete we can import this data back into Revit and all of our piles, their sizes, and the schedule is updated automatically. It is clear how we are minimising risk of manual data-entry errors, saving time because it’s quicker than the designer hand marking a schedule and we are also saving some trees with the reduction of paper. As the design progresses and further changes are required the excel spreadsheet can simply be updated as necessary. This process can easily be replicated across other elements in the bridge including bearings and girders.

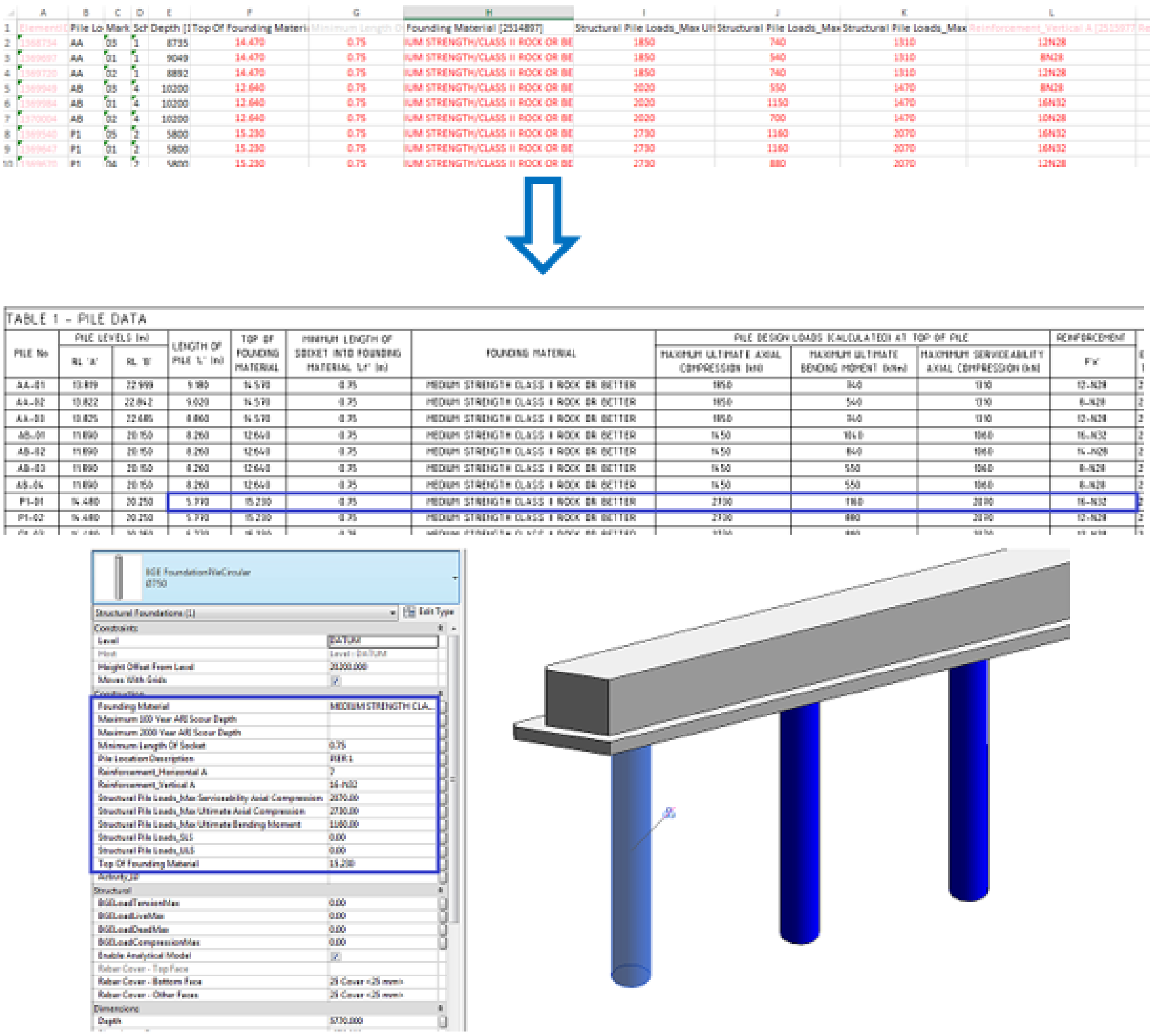

Figure 3.0. Sharing design data across different software platforms.

Another example is how we can use the model to automatically generate setout points for our deck, based on the 3D road alignment. Traditionally this process would be done with a series of calculations or in an excel spreadsheet and data transferred to the drawings. Things tend to get interesting when you introduce more complex geometries and sometimes the spreadsheets can be incorrect. This process alleviates the risk and time spent rectifying changes if errors are found. We can take our 3D modelled deck in Revit, use an add-on to Revit called Dynamo Studio, analyse the perimeter of the deck to get the Easting, Northing and RL data at various cross sections, perpendicular to the control line. This information is then stored in the model and a schedule can be generated and placed on drawings. If the road alignment changes the information can get updated with a couple of clicks of the mouse. A similar workflow can be used to extract setout data for elements such as piles, bearings and the bridge setout itself.

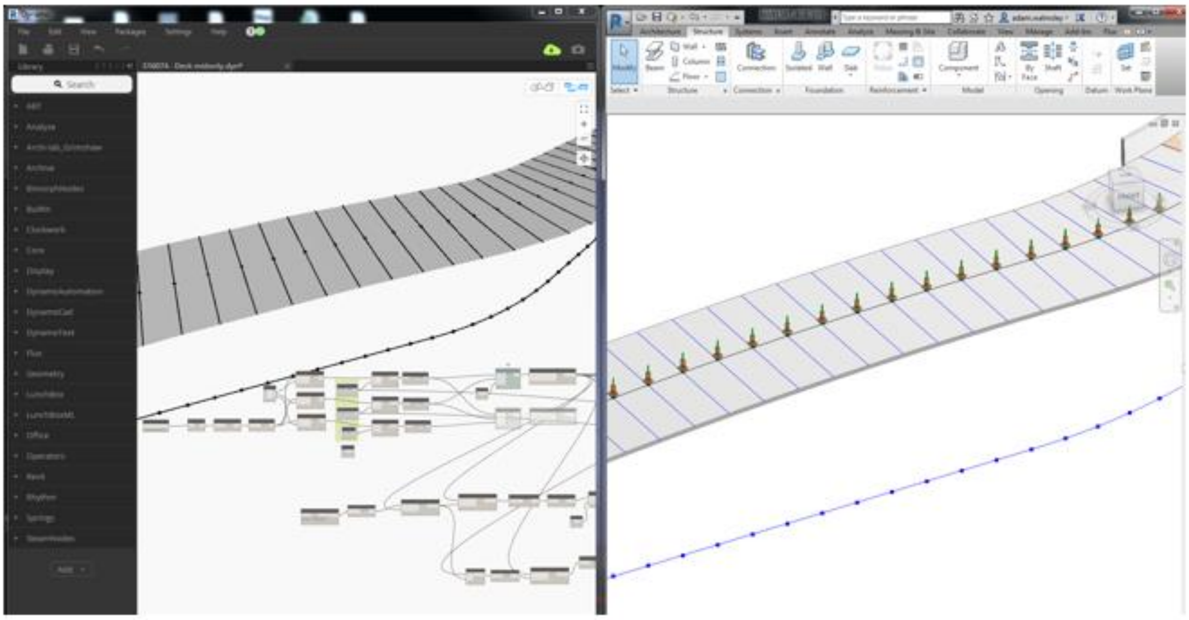

TABLE 1 DECK SETTING OUT

LOCATION	CHAINAGE ALONG CONTROL LINE MC20	CO-ORDINATES		POINT ①	POINT ②	POINT ③
		EASTING	NORTHING			
	0.000	333856.352	6248931.514	21.643	21.551 *	21.736 *
	0.000	333857.810	6248932.883	21.474	N/A	21.567
	0.000	333859.268	6248934.251	21.326	21.234	21.419
END OF DECK ABUT A	31.966	333726.059	6248859.416	24.644	25.810	25.493
	32.000	333759.481	6248864.836	30.332	30.240	30.425
	36.000	333816.934	6248894.562	29.509	29.417	29.602
	38.000	333827.183	6248904.142	27.404	27.312	27.497
	40.000	333859.268	6248934.251	21.326	21.234	21.419
	42.000	333726.093	6248859.415	25.649	25.557	25.742
	44.000	333728.093	6248859.402	25.933	25.841	26.026
	46.000	333730.092	6248859.432	26.216	26.124	26.309
	48.000	333732.091	6248859.504	26.500	26.408	26.593
	50.000	333734.088	6248859.617	26.784	26.692	26.877
	52.000	333736.082	6248859.773	27.068	26.976	27.161
	54.000	333738.072	6248859.971	27.351	27.259	27.444
	56.000	333740.058	6248860.210	27.635	27.543	27.728
	58.000	333742.038	6248860.492	27.919	27.827	28.012
	60.000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 1 DECK SETTING OUT

LOCATION	CHAINAGE ALONG CONTROL LINE MC20	CO-ORDINATES		POINT ①	POINT ②	POINT ③
		EASTING	NORTHING			
	108.000	333789.940	6248874.646	31.945	31.853	32.038
	110.000	333791.844	6248875.259	31.920	31.828	32.013
	112.000	333793.730	6248875.925	31.880	31.788	31.973
	114.000	333795.570	6248876.708	31.826	31.734	31.919
	116.000	333797.357	6248877.604	31.756	31.664	31.849
	118.000	333799.086	6248878.609	31.672	31.580	31.765
	120.000	333800.748	6248879.721	31.573	31.481	31.666
	122.000	333802.337	6248880.935	31.459	31.367	31.552
	124.000	333803.848	6248882.246	31.331	31.239	31.424
	126.000	333805.307	6248883.614	31.188	31.096	31.281
	128.000	333806.765	6248884.982	31.030	30.938	31.123
	130.000	333808.224	6248886.351	30.857	30.765	30.950
	132.000	333809.682	6248887.719	30.669	30.577	30.762
	134.000	333811.141	6248889.088	30.466	30.374	30.559
	136.000	333812.599	6248890.457	30.249	30.157	30.342
END OF DECK ABUT B	137.469	333820.962	6248898.304	28.718	28.626	28.811
	138.000	333814.057	6248891.825	30.017	29.925	30.110
	140.000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 4.0. Computational design data for setout of complex geometries directly into the 3D model.

Of course, there are many other BIM processes that can be adopted to aid the design process. Adding rebar to complex bridge geometries can definitely be worth the investment. Assembling the rebar first digitally before it gets scheduled and delivered to site will reduce time spent installing the rebar, will reduce the number of RFI's and you can be assured that the rebar will actually fit.

The bridge model, with all its data is not just useful for the design team. The benefit of adopting Digital Engineering processes across the entire lifecycle of an asset means that this information can be used elsewhere, for other applications. The model can be used for estimating by the construction team, but extracting quantities of concrete is just the tip of the iceberg. There are companies who are doing great things with the technology available and will continue to improve on their workflows as new technology emerges. The use of Augmented Reality and Virtual Reality is becoming quite common. It is simple and inexpensive to take the consultants' design models and place them into real world, digital environments. Construction teams can also use the accurate models for construction sequencing, space proofing and ultimately reducing down time on site. They can use the models to track real time progress of the construction of bridges and compare that with costs vs. the initial time estimated. This is known as 4D and 5D BIM. Point cloud laser scanning and photogrammetry is another technology that is being adopted by our construction teams and is a useful technology for us as bridge designers. Consider the ability to send a drone in to inspect bridges in remote areas, or for the drone to be able to get close to structure over water that may otherwise be harder to access as humans. The drone can capture incredibly detailed laser scans of the existing elements and can be reviewed in the office. We have used the same photogrammetry technology to assist us with a bridge replacement project shown below. The existing structure was captured digitally and overlaid with the proposed 3D bridge geometry. The model was used extensively by the construction team in preparation for the site works and was used by us as designers throughout the design phase.

Figure 5.0. Laser scanning of existing bridges with the proposed bridge geometry shown in dark red.

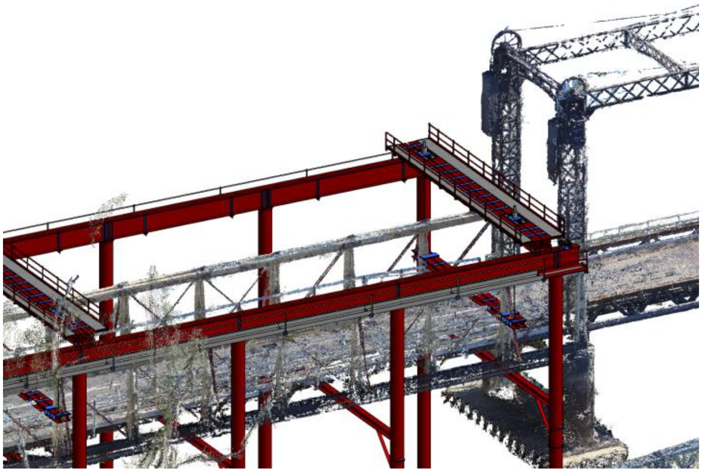

Figure 6.0. Close up of detailed bridge geometry with laser scanned existing bridge.

You may hear comments that adopting digital processes is too expensive of an investment for little or no return. As a team of bridge designers there are very clear and obvious ways that time and money can be saved by introducing digital technologies. Companies need to invest in identifying their key staff who understand the changes that are happening in the industry. People who understand technology, can manipulate data and connect the information between the many types of design software available to us. Some of the examples that have been demonstrated in this paper only scratch the surface of what is possible with the use of the technology available to us. It can often be considered a daunting task to take the leap from traditional workflows into the 3D Digital Engineering environment. Some may question why they think the industry is reinventing the wheel, however my response is that we are simply putting on better tyres. Many benefits can be instantly gained by starting with small and simple projects rather than trying to dive into the more complex bridge structures. Ironically, these more complex structures tend to be the projects that benefit the most from adopting BIM processes during all phases of the project lifecycle.

CONCLUSION

There is no hiding how far digital technologies have come in a short period of time. Consider the smart phone as an example. 10 years ago the smart phone concept was only new and now look at what can be done from the palm of our hands. Who knows where we will be in another 10 years with smart phones. The same can be considered with Digital Engineering technologies. Even though as an industry we are down the bottom of the digitisation investment list there are still many software companies developing and implementing exciting ways to work in our industry. In the not too distant future the term Digital Engineering and BIM will cease to exist. Similar to the way CAD became the norm, it will simply be the way that we design, deliver and manage projects. We are still in the middle of a complex change period in our industry and although we may be a few steps behind the smart phone the future is definitely looking promising!

REFERENCES

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